

**Interface Design for Spatial Data Visualization:
A Web-Based Integrated Multimedia Approach for the Tren Urbano
Project**

by

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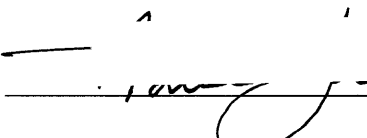
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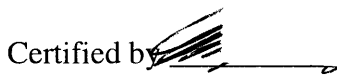
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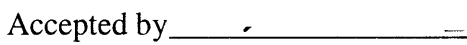
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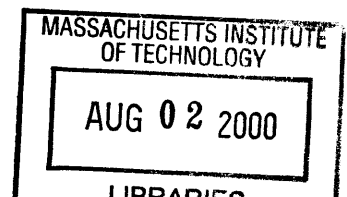
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Abstract

The thesis focuses on the uses of information design to enhance Technology Transfer among professionals, staff and students involved in the Tren Urbano Project, a rapid transit system for San Juan, Puerto Rico. Graphical representation of data such as images, motion video, audio, and hypertext in a distributed web-based environment can help people to understand the complex issues surrounding a transportation planning process and help to facilitate transfer of skills and knowledge between professionals, students and faculty.

As part of this process, a web-based, integrated spatial multimedia system was developed to provide the project participants with an online spatial resource center that can be expanded in the future to accurately document the construction process and spatial characteristics of the proposed train alignment in Puerto Rico.

The thesis describes the approaches and challenges of constructing a spatial information infrastructure in a distributed, multi-platform, web-based environment. Furthermore, it illustrates the implementation and evaluation strategies used in the project. The implementation strategy included distribution of CDs to the various parties while evaluation strategies consisted of user responses from interviews and surveys.

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Biography

Prior to joining the Urban Studies and Planning Department at MIT, Adrienn Jankovics has earned a Bachelor of Arts in Geographic Information Technologies and Earth Sciences at the University of Massachusetts Boston where she focused on GIS applications in the urban planning and economic development fields. At MIT the author concentrated on information technology, real estate development, GIS and multimedia representation under the Planning Support Systems Group in the Department of Urban Studies and Planning.

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CHAPTER 1:

INTRODUCTION

1.1 Information Sharing in Traditional Planning Environments

Central to the success of a large-scale transit projects is the free-flow of communication among the parties involved. However, for reasons such as disperse information sources, inadequate institutional effort and varying time and space elements, discourse and involvement can prove somewhat inadequate. The US Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) was created in order to allow new, innovative methods to be developed in order to enhance public and private sector participation during the transportation planning process and to help the Metropolitan Planning Organizations to develop collaborative decision making strategies.

Success in any project almost universally requires consideration of multiple viewpoints using a variety of information sources. The ability to present this information graphically facilitates a better understanding of complex phenomena while stimulating creative problem solving. In sum, visualization aids in communicating with others (Lagendorf, 1992).

“Visualization is a method of computing. It transforms the symbolic into the geometric, enabling researchers to observe their simulations and computations. Visualization offers a method for seeing the unseen. It enriches the process of scientific discovery and fosters profound and unexpected insights. In many fields it is already revolutionizing the way scientists do science” (McCormick et al 1987, p.2).

According to Lagendorf, “computer graphics can aid creating alternatives, and facilitate communication with others. They may also facilitate group participation in analysis and planning and contribute to conflict resolution and decision-making” (p.737).

Visualization of information can not only facilitate greater understanding of the planning process by providing information in an easily understandable format, but can also aid in the organization,

analysis, and communication of a large amount of complex spatial and non-spatial data. Furthermore, visualization of information can also facilitate group participation and conflict resolution.

1.2 Statement of Problem

In any large-scale transit project, the many project participants store a vast amount of information regarding existing conditions, plans for the future, financial data and the like at various locations and in different file formats. These may take the form of census data, printed reports, maps, minutes of meetings, photographs, drawings, cost figures and images that participants must retrieve manually from a number of locations.

The Tren Urbano project is the largest public transit construction project in Puerto Rico. In this environment, technology transfer require the collaboration of professionals, academics and students at the various research institutions, and public and private agencies affiliated with the project. In the Tren Urbano context, not only data sources are in different formats at different locations with different people, but researchers are also geographically isolated from one another, which makes data sharing even more difficult. Especially for those researchers who are located in the Boston area at various research universities, retrieving digital data can be very time consuming and difficult. Because of this disperse situation, most people are not even aware of the vast amount of graphics, aerial photographs, videos, maps, and research papers that have been collected by the various members of the Tren Urbano community. More specifically, project specific information and digital data reside both in Puerto Rico and in Boston in several universities and offices. Moreover, most people do not have access to all the specialized software packages to accommodate the various file formats of the existing data. Therefore, the author believes that a central data repository should be developed to connect the researchers and professionals to an easily usable, accessible, interactive system that is based on an Internet compatible format.

The author assumes that participants can derive a real and tangible benefit from integrating various information elements into a central data repository from a variety of sources and locations. The author also assumes that multimedia and visualization of information can aid

in the process of understanding, organizing and communicating the current and proposed physical conditions of the Tren Urbano project, especially for those who have otherwise no access to the actual project site.

1.3 How Emerging Technologies Can Address this Issue

Emerging information technologies present an opportunity to explore some of the possible solutions to the problems stated above. Tren Urbano professionals, students and faculty can take great advantage of recent advances in computer visualization technologies. These technologies encourage the creation and inspection of multiple views of data sets while allowing users to understand the urban planning project from a spatial and temporal context. In my thesis, I propose to develop and evaluate a technological framework that draws on the advantages and unique characteristics of an integrated multimedia approach. Furthermore, this project aims to demonstrate how project participants can employ emerging information technologies, through multimedia information base, as a medium for communicating, visualizing and understanding transportation planning issues in the Tren Urbano context. In this context, spatial multimedia can help users to translate complex spatial concepts into an easily understandable format.

1.4 Objectives and Goals

This thesis envisions as one major component a finished, web-based prototype that serves as a proof-of-concept platform for a multimedia system supporting knowledge exchange in the Tren Urbano project. Additionally, this thesis will further examine how the use of computer visualization tools and integrated multimedia elements can enhance communication and understanding among users. Finally, this thesis will attempt to better understand those interface design principles that must be applied to achieve the above-mentioned goal.

For example, a hyperlinked image map can provide additional information about a particular place by allowing users to click on a specific location on the map. This kind of information would be much more difficult, if not impossible, to provide via traditional hardcopy paper maps.

In order to achieve this result, one needs to integrate visualization tools such as multimedia into a comprehensive online-resource system that can access and filter a large amount of information from a variety of sources (Shiffer, 1992).

A multimedia approach to illustrating an urban construction project could better present spatial relationships by using the graphical methods of representation as opposed to only textual information. The current technology allows linking descriptive images in order to communicate the physical infrastructure of the Tren Urbano alignment graphically. For example, users can experience the construction site much better by “flying over” it, driving through it, or navigating through 3D maps. The power of such an implementation is that the user can quickly browse the project site and easily “dig” deeper for further information until the desired data is found. Using their mouse, users can select what they want, when they want it, without the constraint of searching through unwanted material.

1.5 Approach

The author will begin by observing information use in the Tren Urbano project and will then initiate a process of determining information sources and relevant technologies. Next, as a component of this thesis, a prototype will be developed that aims to demonstrate how project participants can employ the Internet as a participatory medium and a powerful tool that enables students and professionals to share information and learn more about the Tren Urbano project. Multimedia capabilities help to make complex spatial concepts easily understandable to a broad audience. In the future, the system can evolve to include more interactive features that take advantage of Internet presence. A future platform could entail an interface for discussions or real time contributions by users that enhances the existing spatial information base. The proposed system would provide a significant hypermedia collection of materials through the Internet. Academics, students, professionals and the general public affiliated with the Tren Urbano Project could then gain access to this collection when needed. The author will develop, test, and initially evaluate a networked architecture that not only incorporates the above-mentioned elements, but also has the capacity to describe the current and proposed physical characteristics of the Tren Urbano alignment. In addition to the multimedia platform, the resource center will integrate past

and present student research projects to provide an effective Tren Urbano information clearinghouse.

Students will initially evaluate the system through interviews and surveys. Later on, Tren Urbano professionals and other users will evaluate as the system is fully networked. This thesis seeks to understand how emerging information technologies can enhance communication among different parties and how to develop the best information design practice to achieve this goal.

1.6 Outline of Thesis

This chapter provides a brief introduction to traditional planning methods within a large transit-planning context and discusses some of the challenges these projects face. The author proposes the use of emerging technologies to enhance communication among the parties and will briefly discuss the approach that will be taken in the specific context of Tren Urbano.

Chapter 2 will further discuss the challenges faced by large transit-planning projects, particularly in the Tren Urbano context, and highlight the need for an online collaborative approach for discourse, consensus building, recollection, description and speculation.

Chapter 3 will take a closer look at the strategies for addressing these challenges and provide the reader with some examples of how participants can use multimedia as both a representational and navigational aid, as well as a communication tool, in the urban planning environment.

Chapter 4 will document the specific research approach employed to address these issues in the Tren Urbano context. The author will discuss the general framework used in developing the prototype through observation, identification of user needs, testing and reiteration.

Chapter 5 will examine the system design rationale selected based upon the specific user requirements and observations. It will further explain the general goals and theories of information design and discuss the overall structure of the Tren Urbano project.

Chapter 6 will discuss the specific design structure including both structural and content design. Discussion will highlight the rationale for choosing each element and discuss their constraints and rationale for using them.

Chapter 7 will describe the implementation strategy used to create the online resource center including different distribution methods and delivery modes, their benefits and constraints

Chapter 8 will conclude by evaluating the system and discuss possible further work and the implications for Tren Urbano technology transfer. Finally, the thesis will reveal some of the lessons learned during the research project

CHAPTER 2

TREN URBANO CONTEXT

2.1 General Background of Tren Urbano

Tren Urbano is a federally and locally funded project in San Juan, Puerto Rico to build and implement the region's first public subway system. Some of the benefits are expected to include reducing the current problems of automobile dependence, high levels of traffic congestion, and parking demand in the city. Officials hope that the project will provide an affordable transportation alternative to the local population and act as an economic stimulus for the region. This rail transit system will operate independently of vehicular traffic and serve as a backbone for the San Juan Metropolitan Area with an estimated daily ridership of 15,000. Officials hope to encourage the formation of public-private partnerships and to provide a transit-oriented development pattern around Tren Urbano stations. Moreover, officials hope that the development of an advanced public transportation mode for San Juan citizens will attract more suburban commuter usage. Ultimately this can result in the future expansion of Tren Urbano to additional neighborhoods and communities.

2.2 Need for Online Collaborative Approach

Lagendorf believes that "Computer-aided visualization can make a significant contribution in selecting, organizing, analyzing, and communicating an understanding derived from massive amounts of data." (p. 726). He further substantiates that there is an added value in displaying information from a variety of sources and that visualization tools can help in understanding an increasingly multidimensional world. For example, images have been used together with maps to more accurately express the reality of a location. Integrated multimedia allows various members from different background to see different representations of the same information in order to

relate to each other better. In addition to this, a need is identified to interact with the different multimedia elements. Users might have access to annotate a map or add notes or contribute additional images to the site. (R.M. Jones, p. 125)

A collaborative approach to planning problems fosters greater understanding, synergy and strength that can create a better solution than individual work. However, teamwork can also be challenging because we have learned to achieve goals individually. Questions that often arise during planning processes include *what if*, *what is...*, and *where is...* types of questions that can be both answered traditionally with only textual information or graphically, with a combination of maps, images, and animation. Attending planning meetings can be quite confrontational. This can serve to discourage participation by those who do not feel comfortable voicing their opinion in such an open context. These public meetings also tend to have a restricted time and place that can further limit some participation.

Therefore, a computer based, collaborative planning support system that allow participants to address these questions in a variety of ways is needed. Collaborative public consultation in local decision-making can happen through an Internet based approach where meetings are not restricted by time and geographic locations. The information is available at any time and at any place. This opens up opportunities for more people to participate in consultations and feel more comfortable voicing their opinion.

2.3 Challenges in the Tren Urbano Context

Students and faculty members of the University of Puerto Rico, Boston University, Northeastern University and the Massachusetts Institute of Technology work closely together to research the impacts and issues surrounding the Tren Urbano project. The members of the Tren Urbano community, namely the faculty and the students expressed a desire for an online resource center that would incorporate various graphical elements and help students and others familiarize themselves with the project. This is especially important in this context because many students are not aware of the available information compiled in both the Tren Urbano office in San Juan,

at the University of Puerto Rico and by other students and faculty members. Participants of this research project, especially from remote locations, have a need to visualize the physical environment of the Tren Urbano area from their current locations.

There is a large amount of imagery that has been generated for the Tren Urbano project that resides at different locations in the central office in San Juan. Yet, a system hasn't been developed to take advantage of the enhanced value data integration can offer. Currently, visual materials such as images, photos, models, maps, videos that are relevant to the Tren Urbano site reside in different departments with different people. The request and exchange of these materials have to be through traditional methods such as in person, or by mail, phone, or fax, which tend to be time consuming and inefficient. Some of the challenges facing this knowledge exchange among the various participants such as governmental officials, professionals, students and faculty include the geographic barriers that exist between them and the difficulty of sharing and having access or knowledge about available information.

According to Sventek (1987), multimedia integration occurs at three levels. At the physical level where digital data is connected physically, at the service level where multimedia integration is achieved through a common interface and at the human-interface level that describes the presentation of the different media to the user. Therefore, the integration of digital data is key to capitalize on the potential of computer technology. With digital data, information can be stored and managed by the computer and it can be easily editable and improved upon. Its flexibility also allows for easy update and interaction. The need to organize and interpret various data and information sets has become increasingly important as we have vast amount of information available. In this context, an online-resource center for both the students and the professionals involved in the Tren Urbano can aid in the understanding and communicating relevant information.

The development of an integrated multimedia prototype encompassing various elements from different sources will be beneficial for the students, researches, faculty and professionals of the Tren Urbano project who will be able to use this source in the future as an online resource center to learn more about each others' research projects, the physical characteristics of the Tren Urbano, and the proposed development. A central data repository that is easily accessible to all members can provide a new platform for communication and a learning resource. In the future perhaps, as the system develops and goes on-line, it can be used as a marketing tool to present

the results and progress made with the construction of the subway line. The goal of the project is to increase access and sharing of information to all the people involved, both in San Juan and in Boston.

However, some of the challenges in the Tren Urbano context include the difficulties of using technologically advanced tools, the difficulty in accessing the existing information available and the individual orientation of most software packages. According to Shiffer these limitations certainly are not the only ones, but are the most universal and tangible in nature. The “human-computer interface” problem occurs when individuals who are not technically sophisticated cannot take advantage of the tools offered. Therefore, there is a great need to develop easily understandable, visually attractive applications. Shiffer provides us with an example of a graphical interface that “...is the input of values using sliding bars that immediately interact with an algorithm which, in turn, displays a graphic image to signify the output of the model being used. Rather than implement analytical models by typing cryptic code or numbers, planners can point to maps and photos, slide graphs and bars, and push on screen “buttons” using a direct manipulation interface in order to elicit a response from the computer” (Shiffer,1992, p.4). Also, by representing information in multiple ways, users can view information from several different perspectives thus helping in their analytical thinking. In the Tren Urbano context, users are able to view station specific information such as images showing the construction progress made over the course of months in addition to a series of documents relating to that specific station. Without an integrated on-line system, this kind of communication is difficult since the various elements such as video tapes of the site, photographs, documents, maps and student projects all reside with various people at different geographic locations.

CHAPTER 3

STRATEGY FOR ADDRESSING CHALLENGES

3.1 Previous Work in Integrated Multimedia

“Tell me, I forget.

Show me, I remember.

Involve me, I understand.”

(Moore and Davis 1997)

Hypertext is a highly flexible system that allows users to select and vary the order in which information is viewed. Consisting of multiple pages and multiple links between and within the pages, text can be read in a non-linear format by following links within the pages. The Web’s inter-linked structure was developed to support the handling of such interlinked non-linear text, allowing worldwide availability to a network of documents. Hypermedia is the organizational structure behind the information whereas multimedia is the display of information. With interactive multimedia, users can navigate among many different media types. Multimedia systems support various media, (such as text, images, sound, and video). Together, these media can powerfully convey messages that have a spatial orientation.

According to psychological research, hypertext parallels human cognition and promotes better understanding and decision-making. Indeed, N. Ramarapu (1996) concludes “decision making performance will be superior when information is presented in a hypertext format” (p.191). His research deals with *superficial tasks knowledge*, which includes facts, rules, sensory, and *casual task knowledge* principally associated with tasks that involve the extraction of limited amounts of data that delve deeper into reality. An example of task knowledge is a transportation and land-use link in which the relationship between the data is more important than the data itself. According to Ramarapu, a good match between information presentation and type of task knowledge will improve simple decision-making processes. In sum, planners can greatly benefit from hypertext’s great potential to improve the understanding of presented

information. Nevertheless, information system designers must first identify the requisite type of task knowledge within a planning context before designing a presentation approach (i.e. sequential or multimedia based).

Shiffer's (1992) Collaborative Planning System (CPS) project conveys both the spatial, political and economic information through the usage of sound, imagery, video, text and animation. This type of implementation of a multimedia system helps to illustrate the benefits of these systems in supporting the planning participation process. Some of these technologies include audio recordings, visual recordings (e.g. digital or nodal video), and images or aerial photographs to illustrate an area and GIS to provide spatial information and display. These are only some of the categories available to spatially educate users and enhance public participation in the planning process. Even simple maps, charts and photographs have been useful communication tools for planning purposes. Shiffer proposes three areas of research regarding the use of information technology to support community planning, "the representation and use of the technology; the institutional mechanisms and techniques necessary to sustain its implementation; and issues of access to the IT tools that might be employed." (Shiffer, 1996). As multimedia facilitates greater information, access, and participation, the volume of citizen participation will also increase.

A web-based application is potentially accessible to anybody anywhere. The design of such an application must address the unique technical, social and political dimensions. While planners can use many different technologies to increase the involvement of the public, spatially educating the audience is critical. The technology employed, while suiting the locale's needs, must be appropriate to the decision environment. Greater involvement in the planning process through the use of multimedia may lead to a greater understanding and acceptance. Many public meetings use enhanced visual effects to communicate the planning process, but it is equally important to understand the spatial relationships described on maps. The use of these emerging technologies on the Internet promotes participation and greater understanding. Though Information Technology (IT) is the modern way to communicate information, Shiffer (1996) observes that "Information is only powerful when it is effectively comprehended by those who use it. IT can help people to comprehend information, (thereby delivering knowledge)." He and others have demonstrated that spatial information, such as GIS, images, animation, aerial

photography, nodal videos, and even audio/video recordings, can be provided to enhance the geographic understanding of the planning process.

Involvement of the public requires several modes of communication, including the presentation of information to the public, the receipt of information from the public, and the exchange of ideas and opinions. This might include tours that familiarize the planning participants with existing conditions and future improvements of an area in an effort to raise their awareness of a project's context.

3.2 Multimedia as a Planning Tool

While paper maps, pencils and whiteboard are cheap and effective uses of low technology in many communities, the delivery of multimedia applications over the Internet can maximize the exposure of public access. Multimedia planning tools are considered an integrative set of technologies that serve to promote public participation, communication and information. The rapid advances in technology allow technically unsophisticated users access to these applications with a modem and an Internet browser. The Internet also provides easy access to additional on-line information that can enhance and add value to a particular application.

Shiffer has developed several hypermedia projects that incorporate different multimedia elements to portray the issues relevant in an urban planning context (such as site specific descriptions, general plans and proposals). Through a collaborative planning system, he has developed a technology that not only organizes multimedia to enhance the representation of otherwise quantitative information, but also provides a platform for 'real-time' annotation of maps with text.

These projects convey both the spatial, political and economic information through the usage of sound, imagery, video, text and animation (Shiffer 1992). This type of implementation of a multimedia system helps to illustrate the benefits of these systems to support the planning participation process. Some of these technologies include audio recordings, visual recordings (e.g. digital nodal video), images or aerial photographs to illustrate the area and GIS to provide spatial information and display. These are only some of the categories that one can use to spatially educate users and enhance public participation in the planning process.

3.3 Multimedia as a Communicative Tool

Lagendorf (1992) provides us with an example of using multimedia as a communicative tool in a neighborhood planning study context. Information such as census and other statistical data are incorporated into a GIS system to create a slide show that illustrates the process of neighborhood change using traditional thematic maps. Furthermore, image databases are searched for a variety of visual elements (e.g. photographs, aerial photos and videos) that are then correlated with the map information to provide a further visual analysis of the neighborhood. The results can be linked with text, maps and other images to enrich the description of the neighborhood. The ability to fully integrate this diverse set of data encourages and facilitates greater collaboration among planners, other professionals and the public. The result is a richer set of interpretations, analyses and recommendations.

3.4 Multimedia as a Presentation Tool

The development of representational aids such as visual elements allow users to understand complex ideas in an understandable way. A representational aid in the Tren Urbano context can illustrate what the current station area looks like or give a realistic sense of the train alignment through the use of flyover videos. According to Shiffer (1995), representational aids can either make it easier for users to interact with the computer, or the computer's output is more understandable for the user. Advances in computer technology shifted the input aids from command driven language to visual interfaces like the Web. The previous method meant that users would have to have a deeper understanding and knowledge of computers and commands to even perform simple tasks. Therefore, those who did not have the appropriate knowledge could not participate in this process.

As Shiffer points out, an example of a “gestural interface” is a navigational tool that shows digital video images. This technology was used in the Tren Urbano context whereby

users have full control over the playback of video flyovers and object model videos. The user can play the video back and forth, choose the desired speed of the play and experience the illusion of flying over the particular area. The above described representation of a planning situation permits the user to investigate the situation from different perspectives and generate alternative solutions or approaches. Shiffer, for example, illustrated the concept of average daily traffic count for automobiles by graphically displaying it with a bar and dynamically displaying it with a clip of digital video and audio. The user can point to a different location on the map, which causes the bar to fluctuate. Through the use of the various representational tools, planners and community groups with even limited computer knowledge can be empowered. Some authors suggest that a positive interface can have a positive psychological effect on users who will be more likely to explore the given issue further. These tools are not a replacement but an addition to the traditionally used quantitative display of information. However, as Shiffer points out, one needs to be careful in evaluating the accuracy of these technologies because it is just as easy to misrepresent as to represent a given environment.

3.5 Design Approaches to Collaborative Planning Systems

The challenges of the traditional method of presenting information in a singular way often times does not effectively communicate the example of how crowded streets can be, or how a planning project progressed over time. It is important to make this new technology easy to use, more understandable, more appealing and easily accessible for everyone. Successful implementation of a Collaborative Planning System can lead to greater communication among the members in a group-planning situation and provide increased access to information (Shiffer, 1992).

The best example of integrating multimedia is the Web, which allows one universal interface for all kinds of different media. Urban planners are among the professionals who will benefit from this technology. However, it takes time to make the transition from old to new technology. There has been a lot of research regarding new ways of communications in urban planning. For example, Shiffer (1992,1995) has designed and developed a collaborative planning system that demonstrates multimedia applications can be very effective in handling complex urban planning

issues. A project called 'Townplanner', an image map application developed by Kiib and Veirum (1993), creates a virtual desktop for planners to gather planning related information that are then geographically referenced to a map.

Multimedia techniques offer a whole range of possibilities for visualization, investigation and demonstration. Some authors, such as Weidenmann (1991), Dreher, and Mack (1996), articulate four types of functions that media might have including the *function of demonstration*, the *function of putting into context*, the *function of construction* and the *function of motivation*.

The *function of demonstration* helps users who are not familiar with the specific topic or planning situation to gain a better understanding by offering images, animation and graphic representation about the characteristics of the object. For example, traffic noise of a planned road can be illustrated with sound technology. In the Tren Urbano context, users are presented photographs illustrating the physical characteristics of current station areas.

The *function of construction* helps users form a model of knowledge about the given topic and its relations. Instead of pictures, one can use maps, graphs and diagrams to display information about quantitative or qualitative facts. Again, daily traffic flow can be illustrated with an animated map showing the traffic's spatial and temporal distribution. In the Tren Urbano context, users can view additional information in a form of text, graphs, diagrams and maps about specific topic areas or specific stations.

The *function of putting into context* helps users familiarize themselves with the overall concept. Textual information as well as satellite images or vide can aid creating a spatial context.

Finally, the *function of motivation* should serve to further interest the user. One of the best examples of this is a 'fly through' that allows users to explore the given area from a bird's-eye view. Due to our limited cognitive capacity to store new information, any one particular media element should not overload the user with too much information. This applies especially to dynamic presentations such as animation or video that can convey a lot of information at the same time. However, the benefits of presenting information through maps, text, pictures and videos increase the effectiveness of learning the particular urban planning application. In the Tren Urbano context, fly-over videos are presented to illustrate the progress of construction over time.

In urban planning, it is very important to be able to imagine the future physical elements such as the buildings, roads, trees and houses. Traditional methods include illustrations and drawings of the proposed plan and the building of miniature models. One of the major disadvantages of these is the inability to dynamically change the model or illustration.

A successful Collaborative Planning System has a double objective of producing knowledge and action directly useful to a group of people and to empower these people further by allowing greater collaboration among them. Thus, it is important to design a system that encourages participation by the users, and focuses on collaboration and education. This can be achieved by developing a system that encourages user participation. In the Tren Urbano context, a feature can be developed that allows users to directly contribute additional research projects, papers, or any kind relevant visual elements to the site.

A great need exists to develop tools that enable the technically less sophisticated to integrate, access and filter large amounts of information from various data sources and execute these in a format that aids group cognition (Shiffer, 1992). Collaborative Planning System offers such characteristics and allows for analysis, forecasting and performing “what if” queries. This system offers a visual way of presenting information that can be organized to display spatial, political and economical information related to urban planning to enhance the traditional spreadsheet database approach.

CHAPTER 4

RESEARCH APPROACH

4.1 Research Questions and Issues

The goal of this project is to provide enhanced information to the participants of the Tren Urbano project. This information includes the physical characteristics of the various Tren Urbano sites and their surroundings, and the physical and socio-economic contexts via maps, aerial photos, videos, object models, graphics, text, and photographs. Moreover, an objective is to enable students from both Puerto Rico and Boston to have the opportunity to view each other's research projects and documents in productive research partnerships.

This research project also aims to demonstrate the effectiveness of using an Internet-based approach that acts as a resource center and to encourage more active participation with the system.

On a theoretical level, the main research question to be explored is: how can one facilitate technology transfer in an urban transit construction context using Information Technology as a catalyst among professionals, academics, government officials and the public?

The author seeks to analyze and understand how collaborative planning systems and computer visualization technologies can be integrated into a transportation-planning context in order to facilitate greater understanding of the process. Though the Tren Urbano project serves as a case study for the thesis, the general principles can be applied to a broader urban planning context.

4.2 Work Flow Diagram

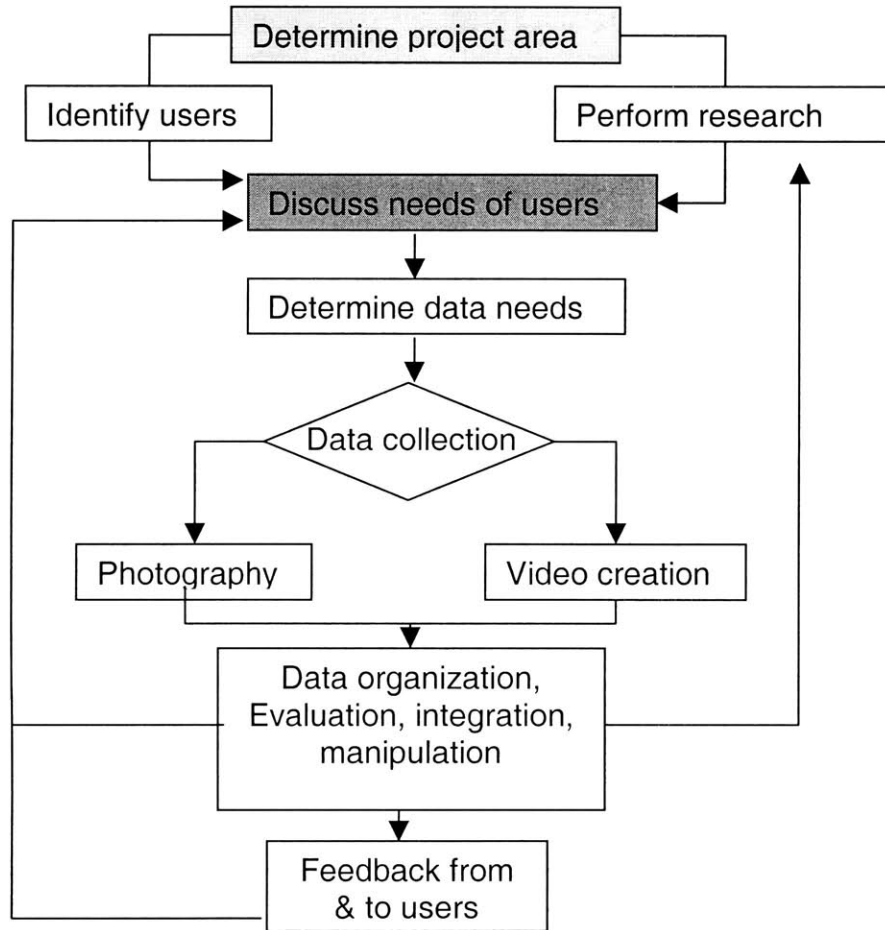


Figure 1: The Tren Urbano Work Flow Diagram

The study area is located in San Juan, Puerto Rico. It is a very lively city that heavily relies on automobiles as the main form of transportation. It is hoped that Tren Urbano, Puerto Rico's first public subway system, will ameliorate the current traffic situation, empower the economically disadvantaged, and create new, lively neighborhoods. Over the past few years, a huge amount of different types of data have been accumulated in the Tren Urbano office (which is currently dispersed in several locations). It was determined that an online resource center would be greatly beneficial for those students who are involved in research projects with Tren Urbano. Integrating various multimedia elements, such as images, existing videos, aerial

photographs and maps, could provide an initial starting point for further work. While the Tren Urbano project already has an official website that includes some graphical elements, the site acts more like a marketing tool in a form of an electronic brochure. This research project differs from the official website in two ways. Firstly, it is organized spatially, that enables users to access information based on their geographic location, and incorporates various multimedia elements. Secondly, it will allow (at a later date) users to contribute to the site, thus collectively building an online spatial database.

The above diagram illustrates the multimedia project's development and implementation process. The project area was determined to be the general alignment of the Tren Urbano subway including station areas. The users were determined to be the students and faculty members from various universities involved in research projects related to Tren Urbano, and professionals directly related to the implementation of the project. While performing user needs determination, literature review was collected and reviewed in order to lay the theoretical foundation for information and infrastructure design. After discussing the needs of the users, especially, the requirements and expectations of students, the author collected the available and necessary data, in order to evaluate, organize, and in some cases manipulate it. During this process the author reviewed more literature work and maintained an on-going dialogue with students regarding expectations and needs. Finally, the author received formal feedback from users that helped evaluate the current benefits and constraints of the system.

4.3 Identification of Needs

During field work in Puerto Rico, in January of 2000, the author has spoken to both students and staff of the Tren Urbano office in order to determine the user needs for this project. A successful prototype needs to incorporate and integrate the users' conceptual model. The author also needed to determine the appropriate use of media for the project, and ways to support it in the prototype. This closely relates to the amount of data available and the accuracy and appropriateness of the data.

The identification of user needs also included a goal refinement process aimed to discern their specific needs, expectations and desires. It was very helpful to have a working prototype

available for the January site visit that served as a basis for initial discussions. This helped generate many ideas and goals that the author tried to incorporate into the design process. Students, especially those from Boston, were most enthusiastic about having a tool that allows a virtual tour of the project area, so they could become familiar with the site before their January visit.

Also, developing the online resource center, which would allow students to post their work, share their thoughts and form partnerships was well received by the students. The author was repeatedly asked to develop a forum that would enable participants in the research project to collaborate and provide access to other people's research.

Original goals got reprioritized and re-evaluated as the project progressed over time. For example, an annotation mechanism was envisioned that would have allowed users to annotate images and maps 'on the fly' (real time) in order to build a knowledge management system. However, in order to develop this interactive feature that requires sophisticated programming capabilities, the project needs to be networked and available on-line. In January, however, officials of the Tren Urbano were wary of distributing this project online, and the preferred distribution method became a stand alone CD-ROM. Originally, the author also wanted to post the work in progress on-line to facilitate feedback from users while building the prototype, but it was decided in Puerto Rico to keep the project private (off-line), and within the Tren Urbano community. So, the advantages the Internet could offer in this regard were not fully realized. Finally, a major part of the project, the user's ability to upload information real-time was not developed during the course of this project.

4.4 Data Collection and Organization

The Tren Urbano office in Puerto Rico has a vast amount of visual information regarding the construction progress. The Graphics Department has thousands of photographs taken every month on each station and alignment section. They also have CAD drawings of current and proposed stations areas, siteplans, perspectives and 3D models of future station areas, numerous Powerpoint presentations, maps and aerial photographs of the alignment at different time periods. The GIS Department, on the other hand, has a limited collection of very basic

geographic layers such as roads, boundary files, alignment and station points. Despite the abundance of graphic information available, the author found it quite difficult initially to collect any digital data remotely. The author repeatedly contacted several officials both by phone, and email, but until January, all efforts were unsuccessful. The only imagery that was retrieved at this time were the files already available on the official website, and a video segment of the alignment.

During the January visit to the site, however, the author was able to extract valuable data and information by first developing personal contacts. Efforts to collect data would have continued to remain unsuccessful, unless those personal connections with several key personnel have not been made. In person, the author was finally able to collect some basic GIS layers, several Powerpoint presentations, and two CDs filled with construction photographs taken every month for a whole year, in addition to all station siteplans, perspectives, and maps.

In addition, the author performed first-hand data collection by taking aerial photographs of the alignment and station areas and numerous ground level photographs. Also, an aerial video was taped during the January research visit.

4.5 Development of Prototype

The methods used to develop the prototype include both “comprehensive” and “iterative”. The former method is best used when there is enough available data to complete the project. Usually it requires a long time to develop a ready system. In most cases, however, the “iterative” method is suggested because of lack of well-defined goals and problem areas. Shiffer suggests starting the development of the prototype with a map and image base that can serve as a starting point to gather more information as the prototype develops. Development time in this method is much shorter and the benefits include the fact that all information will be used. The components and design of the prototype was predetermined by the data that was available. First, a flyover video taken in the summer of 1999 of the alignment was digitized and segmented to cover each station segments along the alignment. Later on, the video digitizing process was repeated with the January videotape. A map of the area was used as the image-base to hyperlink all videos to the corresponding section. The second layer of information displays a detailed aerial photograph

showing a particular area between two stations and displaying the segments included along with the flyover videos. The development of the prototype started with the precise definition of the problem area (i.e. the Tren Urbano alignment).

The initial purpose of the development of the image map and video flyovers was to demonstrate the concept to the members of the Tren Urbano project in the January visit. This way, people could add valuable comments and suggestions as to how to proceed and what information sets they would find useful. Another key component that was going to be built into the system was the ability for users to annotate maps. This could be accomplished by typing text into a field, either within a specific application or the project itself using customized programming. However, Tren Urbano officials were wary about distributing the prototype on the Internet, so this dynamic capability will have to be incorporated in the future. Another approach to annotation can be the creation of objects such as icons, polygons on a given map, and photo or aerial imagery which users can use to annotate information and build an online database. However, this could have been a very technically advanced feature requiring specialized programming and the creation of a real time database that would automatically update the Image map real time. Moreover, a technique is also required to make sure that the users have an option of deleting items from the database or erasing recently made annotations in case of a mistake.

A web-based integrated multimedia approach was developed in order to deliver geographic information by integrating various types of data sets into a central project. This prototype will allow users to experience the Tren Urbano project site as a virtual space and explore spatial information through different media including information about the Tren Urbano alignment and its surrounding area. The physical context is explained partially through text, but mainly through spatially organized multimedia elements such as maps, aerial photos, GIS information, panorama pictures, CAD drawings, photos, and 3D-models.

Part of this objective is the value-added possibility that the proposed online resource center will allow interactivity through dynamic contribution (uploading) by its users that will enable future content expansion of the site. For example, students or faculty members can create their own digital media type such as photos, videos, and textual information and have the capability to upload the particular data to the appropriate place in the system. This means that a user can take a ground level photograph of station A and have the option to upload the file to the

HTML page that contains ground level photographs of station A. By offering enhanced visualization of geographic data through an integrated multimedia approach, an additional objective of the thesis is to facilitate exploration, analysis, presentation and communication among different participants in the transportation context. The author wished to design an interface between user and project site such that would allow the user to have meaningful interaction with real educational value. The author believes that a multimedia approach is a platform for interactive exploration, inquiry and creative application.

The development of the project site involved the use of a computer with an Intel II processor, Microsoft Windows and at least 120 MB of memory and 10GB of disk space. Software skills included a proficient knowledge of HTML, DHTML, Dreamweaver, Photoshop, Quicktime, Video editing and Adobe Acrobat software. An additional challenge was ensuring that the prototype could properly function on both Machintosh and PC machines, and on several different monitor sizes and Internet browser software.

4.6 Reiteration and Testing

A functional prototype was taken on the Puerto Rico research trip in January 2000 and shown to several potential users in an attempt to receive feedback. The author asked them to verbalize what their goals and intentions were, how easy the navigation was and if the content was logically structured. This kind of systematic reiteration, testing and evaluation during development phase played an important role in the process of design and development. Indeed, a fundamental requirement in creating a successful prototype is to have users actively participate in the system as much as possible.

CHAPTER 5

SYSTEM DESIGN

5.1 Philosophy of Information Design

Any computer-based information system has both a *system* and a *human* side. One can develop the system side through proper design while changing the interface at the human side through training and experience. Norman calls the model developed by the designer the “*Design Model*.” The model perceived by the user is the “*User Model*.” The combination of these two models form a physical structure that creates an image of the model dubbed “*System Image*.” The effectiveness of the “*Design Model*” is predicated on the incorporation of user needs, requirements, backgrounds and experiences. Conversely, audience interpretation of the system results in the “*User Model*.” Ideally, this image should be compatible with the intended image built by the designer. Norman describes this idea graphically in the diagram below:

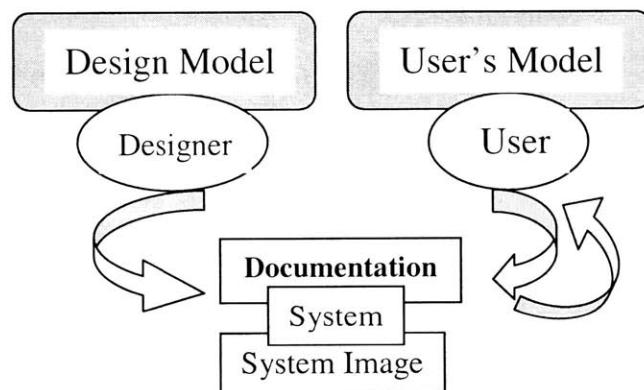


Figure 2: System Model by Donald A. Norman

Figure 3 illustrates the seven stages of user activity presented by Norman (1986). The critical objective of the modeler is to establish a connection between “goals” of the user and the system. This means that one must design an interface that matches the needs and intentions of the users (in this case students, faculty and professionals). The difficulty, however, arises when users in the Tren Urbano case differ in not only their technical sophistication, but also in their needs and expectations of the system. The designer’s primary responsibility is to provide the

users with a coherent, consistent and easily comprehensible design model. The navigational structure, menus, links and buttons can assist users in the stages of action specification (Norman, 1986 p.44).

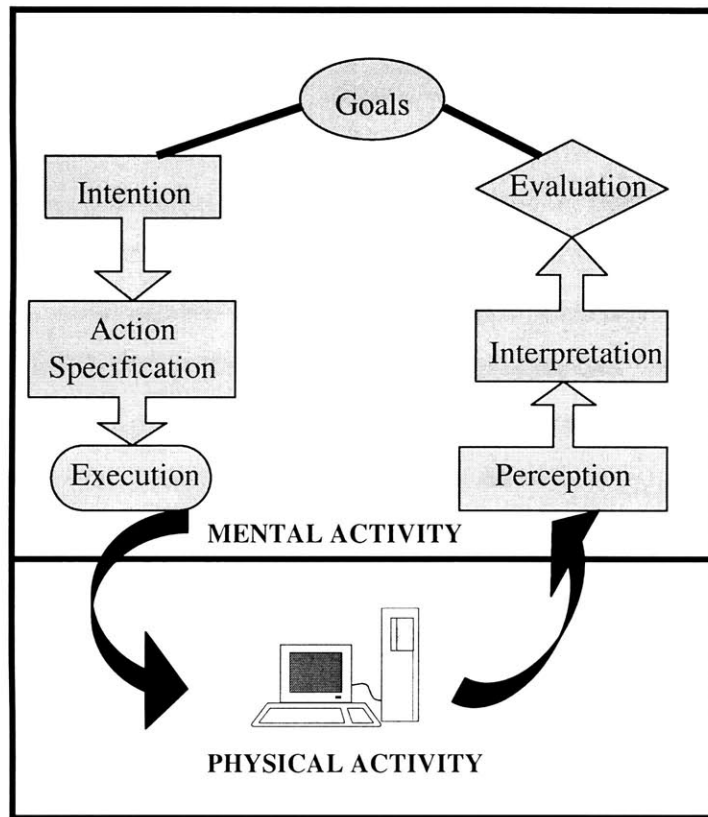


Figure 3. The seven stages of user activities involved in the performance of a task (Norman, 1986)

Information interaction design represents the intersection of information design, interaction design and sensorial design. *Information* design addresses the organization and presentation of data and its transformation into meaningful information. *Interaction* design is the creation of an experience for the users. Finally, *sensory* design consists of the tactile senses (touch), visual senses (writing, graphic design, animation), auditory senses (sound) and olfactory senses (smells and taste). It is important to choose the appropriate media type to create an effective and meaningful experience for the users (Shedroff, 1999).

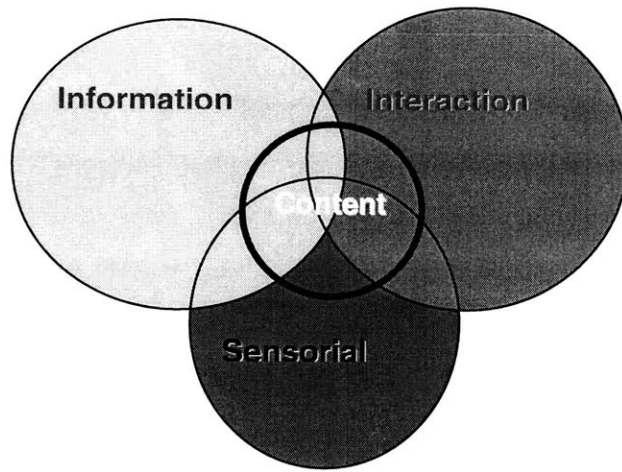


Figure 4: Information Interaction Design: A Unified Field Theory of Design by Nathan Shedroff

Shedroff suggests that designers must organize and transform raw data into information in order to create value for users. Information then can be transformed into wisdom through interaction design. Transforming data into information is done through organizing it in an appropriate way. Organization affects the way people understand the information pieces, so designers must arrange for the most appropriate organization type for a given situation. Designers can organize all data by alphabet, location, time, continuum, number of category, or by random order. Designers most often choose spatial organization for data that has important relations to other data or when things are oriented by their geographic locations, as is the case of the Tren Urbano prototype. Data can also have nested, multiple organizational structure such as the Vietnam War memorial in Washington D.C. Its design allows people to uncover patterns and also experience certain emotions. To communicate effectively, one needs to first define the goals and messages being created by the current organizational structure of the data and communicate this clearly. The designer first needs to ask the audience and find out what kind of experience they want to have.

The purpose of information design is not graphic design, but rather to provide a framework for expressing these capabilities. Data is worthless, unless it is organized, transformed and presented in a way that it makes it valuable. Excellent interface design facilitates the transformation of information by users into knowledge, then wisdom. Designers can build knowledge via interaction design and the creation of ‘experiences.’ In order to build a meaningful experience, one must understand the needs of the audience, their expectations and their abilities. The following diagram illustrates this concept.

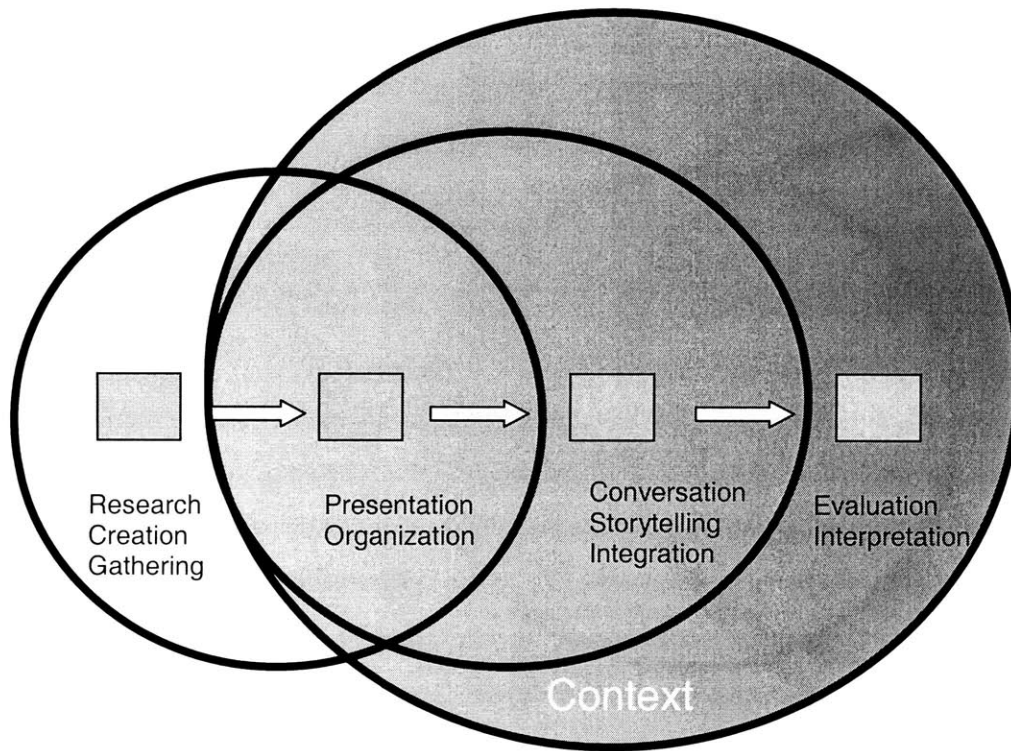


Figure 5: The Understanding Spectrum, Nathan Shedroff, 1999

Figure 5 presents interactivity as a spectrum that ranges from the most passive activities, such as watching television, to the most interactive activities, such as participating in a political debate. We can measure interactivity by audience control, the number of choices this control offers, and the ability to be creative with the given selection of tools (Shedroff, p.273, 1999). Beyond participation in any activity, people inherently enjoy the act of creating. Therefore, systems that allow for active contribution by users enhance the learning process much more effectively than passive systems. In the case of Tren Urbano, interactivity would involve a mechanism whereby users can annotate visual elements such as maps, photographs or other images, thereby adding to an online “library” of thoughts.

Adaptive technologies, for example, allow users to change the experience through agents that ultimately modify behaviors and outcomes. Communicative experiences such as meeting others and sharing stories also offer a high degree of interactivity. Similar to many life experiences, a typical software interface can be described by its feedback and control attributes as well as its creative, productive and communicative attributes and adaptive capabilities. The question still remains, however, as to how designers can create meaningful experiences and

interactions for others. Since all presentation media stimulate the senses (audio, visual and written), it is very important to understand when to apply which medium, and how to coordinate each detail to correspond with the messages and goals of the project. The better the integration of these elements, the more successful the interactive communication will be.

DiBiase (1990) offers a framework for thinking about visualization and emphasizes the role of maps. The key distinction among maps, he argues, lies in the fact that they either foster private visual thinking or public communication.

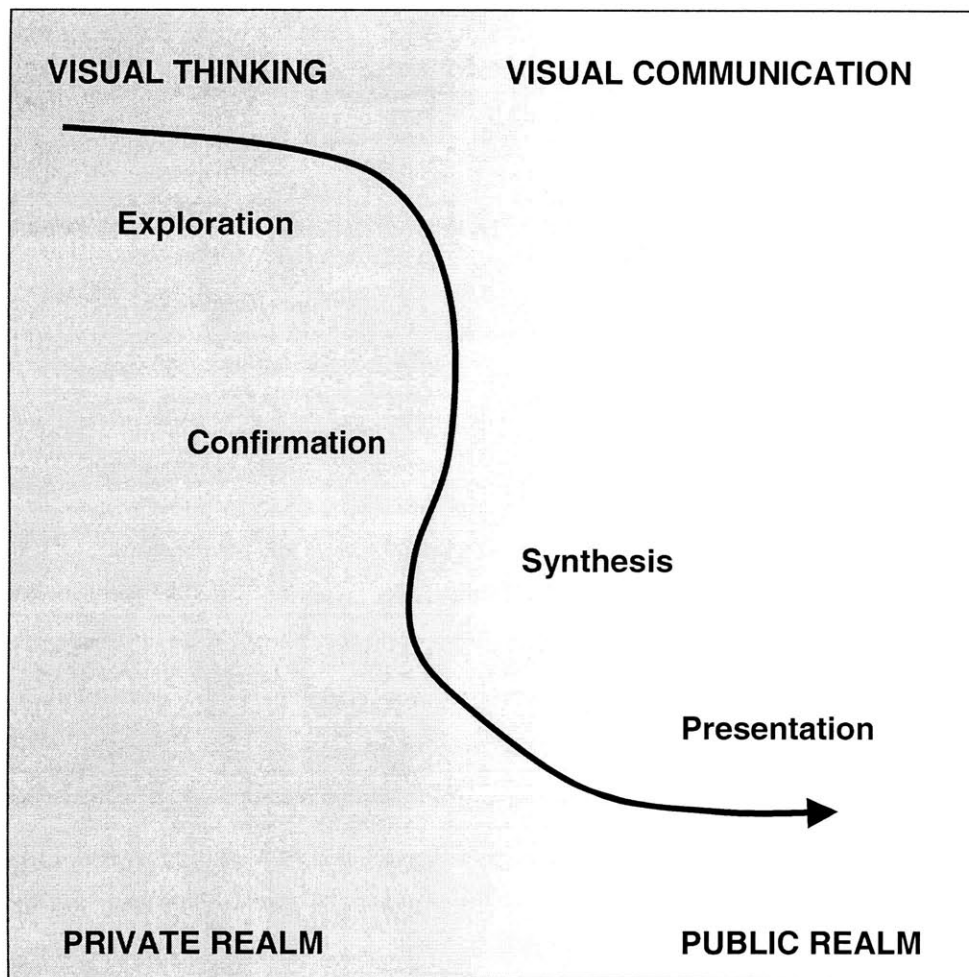


Figure 5: Visualization as a Tool of Scientific Research (DiBiase, 1990)

On the other hand, MacEachren (1994) proposed a different model that emphasizes map usage over map-making approaches. According to MacEachren, map use is best represented as a three dimensional surface. The first dimension ranges information from private to public, the

second toward either revealing known or unknown information, and the third ranges user interaction from low to high.

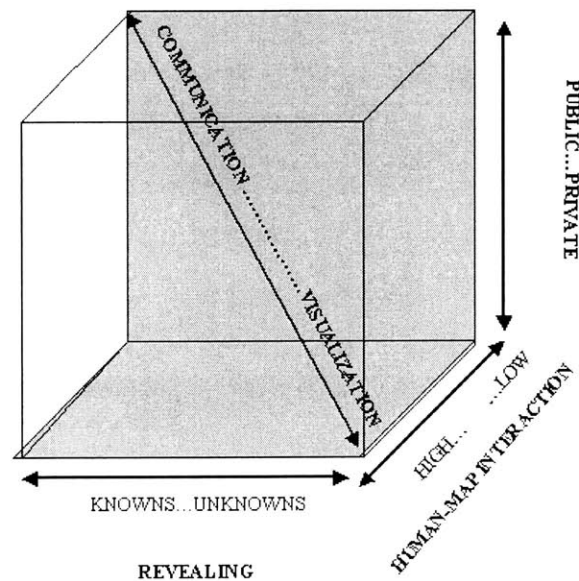


Figure 6: The "Space of Map Use (MacEachren, 1994)

Both MacEachren and DiBiase agree, however, that aside from its role as a visualization tool, communication is the main purpose of mapmaking and map use. Since a great deal of information in urban planning is spatial, this awareness plays an especially important role in employing visualization techniques that will ultimately influence the design and function of the Tren Urbano prototype.

In the following summary the author will describe design approaches and theories that exist regarding computer visualization. According to MacEachren and Kraak (1997), four overall map use goals exist: *Exploration, analysis, synthesis* and *presentation*. Exploration represents an important aspect of information visualization in that it prompts visual thinking, hypothesis generation and testing. Visualization therefore is the cognitive process of 'making it visible' in terms of mental images (MacEachren, 1995). Visualization has three elements that include the graphical representation of data, the use of advanced technology (the interface between data and user) and the production of cognitive representation. Interacting with data from a variety of perspectives is an important element in human understanding. MacEachren suggests visualization tools based on increasing levels of complexity that allow for *identification of spatial and attribute patterns, relations between spatial or attribute patterns, and patterns and*

relations in the spatial-temporal domain. To illustrate the point, some of the above mentioned tools include basic display elements for navigation such as pan, zoom, or scale. Others include query of data, multiple dynamically linked views, and animation.

An additional relevant topic in visualization is the user audience. In the planning context, this audience consists of concerned citizens, experts, technicians, and other decision and policy makers. Because of this, the participatory planning context can become quite complex as each group has a different agenda and varying levels of technical sophistication and experience. In the Tren Urbano context, users reside in a number of locations and consist of students, researchers, academics, professionals, technicians and other policy makers associated with the project. The prototype was primarily created for the academic community and especially for the students. Therefore, their knowledge, experience and expectations are reflected in the design and content of the prototype.

Brenda Dervin (1995) proposes an overview of the history of information theories and methodology of Sense-Making approach that she has developed. Sense making is the theory of practice for information design. It evaluates how people use, interact with and understand information. Dervin derives examples from the comprehension of medical information by hospital patients, the learning of abstract ideas by students, and the understanding of topics by researchers. Sense Making is particularly important in evaluating and understanding the complicated interactions between multimedia applications and users. This project envisions as its goal the application of this information design knowledge to enhance the design of the Tren Urbano project. According to Dervin, humans move through complex time/space contexts in addition to being shaped by their class, race and gender experiences. The author argues that all information is human designed. Sense-Making theory provides a framework that not only helps to design an information system, but also allows people to change and adapt the systems and information as necessary.

According to Dervin, “Sense making...explicitly privileges the ordinary person as necessarily a theorist involved in the development of ideas that provide guidance not only for understanding personal worlds but necessarily for understanding collective, historical, and social worlds as well” (Dervin, 1995). This privilege is the ultimate goal of the Tren Urbano online resource center, not only to present information, but also to increase communication and empower users.

5.2 Rationale of Design Approach

Information systems are concerned with the creation, management, and representation of 'data.' Alone, data bears little meaning until some intermediary organizes it into an understandable representation that allows meanings and patterns to emerge. Site design must have simplicity as its most important element with a very clear information architecture and navigational structure. The homepage, as the starting point in the user's journey, must be very simple and clearly communicate the intentions of the site. From here, the user receives the entry point to the site's navigational structure. The designer should also recognize the importance of allowing users to get back to the homepage in one step from any of the interior pages. We can distinguish between private use or public use, reveal known and unknown, or high and low interactive elements, via representation. In this context, the author designed the site for initial private use within the Tren Urbano community. This type of use also requires a design approach appropriate for a range of individual users. The author developed the Tren Urbano site to initially present the known information and at present does not allow for queries or contributions to the site by the user. Interactive capabilities that permit users to add information to the site via the Internet requires advanced technological capabilities that are not supported at this time. Instead, the prototype presents a diverse presentation of the Tren Urbano project and its associated construction progress, built environment, general context, geography, and future plans. It also provides some textual information about cost, feeder systems, tunneling information and current state of Intelligent Transportation Systems in Puerto Rico.

J. B. Krygier (1997) suggests a possible organization that might better facilitate an understanding of the various multimedia representation methods. Krygier accomplishes this through a resource typology that consists of a range of *representational forms*, and *resource functions*.

RESOURCE FUNCTIONS	Conditional					
	Hierarchical					
	Sequential					
	Animated					
	Static					
		Imagery	Maps	Diagrams	Graphs	Tables

RESOURCE FORMS

Figure 7:Resource Typology (Kygier)

“Static” resources include images, maps, diagrams, graphs, and tables that do not have any interactive features. In the Tren Urbano context, static resources are used to illustrate the physical environment around the alignment and station areas. “Animated” resources, on the other hand, show change and motion when activated and include a great deal of interactivity. This type of multimedia is best used to express changes in time. In the Tren Urbano context, the design incorporates both nodal videos and object-model videos to illustrate the changes made in construction over time. “Sequential” resources allow the construction of linear presentation through a series of navigational elements. “Hierarchical” resources are embedded with other information that can be revealed by selecting specific links. They also introduce the idea of nonlinear means for exploring information. For example, the author used image maps in the project that enables users to acquire more information about specific areas of the map by clicking on the desired location. In the Tren Urbano project, “sequential” resources include all the information that users can explore under the non-spatial section of the project. Finally, “conditional” resource functions such as “what if” scenarios or queries by users produce a solution to a given question based on underlying programming. Currently, this level of interactivity with users is unavailable because it is not linked to a database backend.

The actual site content and structure for the Tren Urbano prototype followed J.B. Krygier’s organizational method. This method explains how one can look at the same information set through a basic set of categories that include projects, time and history, space and landscape, and people and groups. Time and history lends itself to a traditional means of organizing information in a narrative, sequential manner. It is very useful for sites that highlight

the history of a community, or provide historical statistics. One can also organize information in terms of space rather than time. Here, a designer can employ a map to retrieve information about a location selected by the user. The combination of visual and spatial representation allows for multiple scales and ‘elastic boundaries’ and assists in the effort to expand beyond a one-dimensional scale of analysis. Public entities commonly organize by projects, or around a collection of activities and can represent either past or current activities that are also independent of the Internet site. Finally, organization can occur around different groups of people such as a project team, organization etc.

Creating a web site involves the simultaneous activities of authoring the text while considering the message the content should convey to the user. A designer must also consider the layout of the pages, the appropriate amount of graphics to employ the scalability of the project, and the usability of the site (i.e. navigation through the site).

Cartwright (1998) outlines several design approaches to a multimedia prototype. For example, a designer can use storytelling to convey a sense of place to a user. Via multimedia, the user can then choose which path to follow at certain pre-specified points. This framework requires that the designer base the “storytelling” on a spatial organization where elements can vary from sources like text, pictures, animation or video. The user in this sense would control the package within the limits created by the designer. For example, a non-linear approach within storytelling would offer the user a map and, as the user moved the mouse over the screen, hot spots (links) would appear that would offer the user the choice of exploring more information about that part of the map. Alternatively, the user can choose icons on the screen and determine what type of multimedia element he/she wishes to see.

Another method is the “navigator” metaphor that uses a navigational theme-based guide. This includes sequential navigation (cues about where information is located), or visual navigation that provides a plan of the possible paths that users may take. In the Tren Urbano prototype, hot spots on multimedia content such as maps lead to specific information like videos or larger scale maps. Users can then navigate through videos using standard navigational methods via a toolbar and further explore maps through additional hotlinks. Navigational cues such as aerial photographs highlighted by overlays of specific station segments allow users to select the part of the current display that they require more information about. These cues can then lead users to other information external to the current application. In the case of this

prototype, Adobe Acrobat files are embedded in the station specific html document to provide the users with additional information regarding that specific station. In the Tren Urbano prototype, the user has the option to explore more information from general to specific geographic location. The user can quickly browse through the multimedia package to locate information of interest to him/her for further exploration.

CHAPTER 6

SYSTEM STRUCTURE AND CONSTRAINTS

6.1 Structural Design

Interface design should be as clear and user-friendly as possible. The web format allows for menu options, interactive animations, images and textual information to be combined into one interface. The current information structure has three layers allowing the users to go from general to the most detailed information. The most general layer displays a map of the whole Tren Urbano alignment while the most specific layer shows one particular station. At each level of detail, the users have access to corresponding information and an option to either go back to the main menu or to go to the most specific information page. It is important to design a site structure that reflects the user's view of the site and its purpose. Information should always be presented from the user's point of view. The Tren Urbano site is divided into a spatial and non-spatial part that serve different purposes for the user.

This diagram explains to the reader the general organization of the Tren Urbano system. At the top level, the site is divided between non-spatial and spatial elements. The non-spatial part of the system is broken down to additional four categories such as "Facts," "Links," "Map Gallery" and "Student Research". All the pages follow a consistent and easily understandable format with options on the left and information displayed on the right side of the page. This section of the system can be expanded in the future to include either more information for each category, or additional categories.

The spatial section of the Tren Urbano site consists of three information layers. First, the user enters "Information Layer 1" by clicking on the map on the homepage. This page consists of an image map showing the Tren Urbano alignment and its stations and all the textual information regarding station segments and station names. By clicking on either the station segments or the stations themselves on the map, or on the text link, the user has the option to

either go to “Information Layer 2” or “Information Layer 3” respectively. The second layer of information shows the different station segments on an aerial photograph and the fly-over videos taken of that area. The user can go to “Information Layer 3” by clicking on the highlighted station areas on the aerial photographs. This level has the most detailed information regarding the specific station of the Tren Urbano alignment. This page has aerial photos, 3D models, 3D object model videos, oblique views and additional textual information regarding the station. All visual information appears on the right side of the page allowing the user to continuously view the site plan of the station. This also helps the user to better understand the locational reference of each of the graphics.

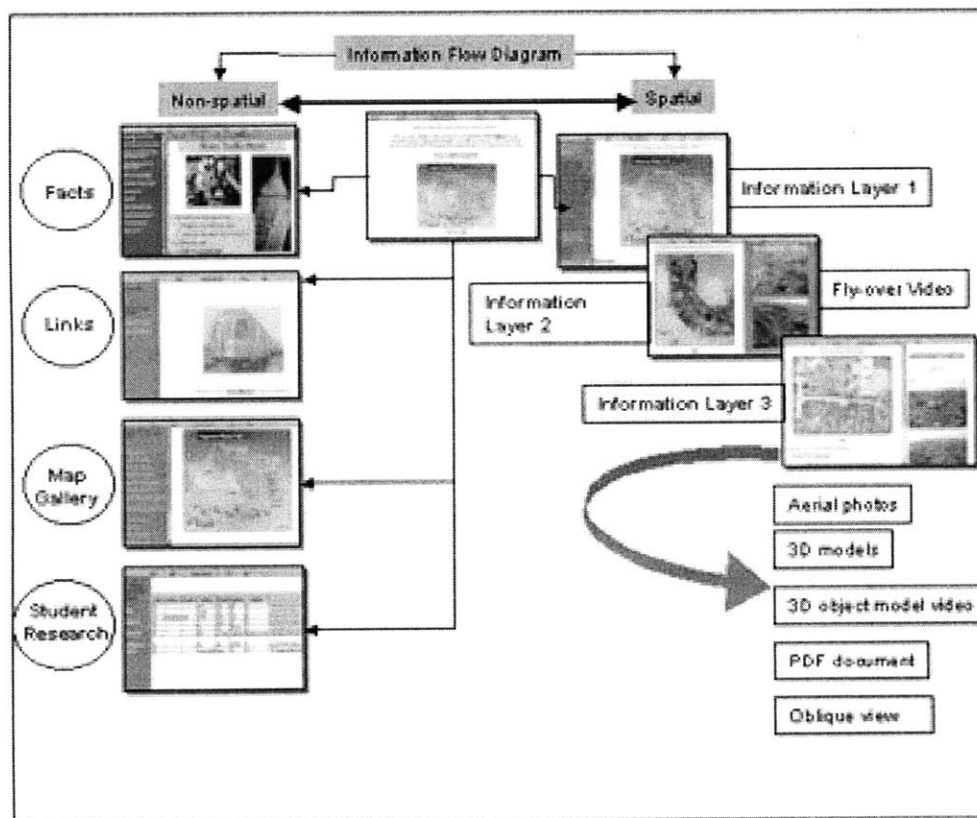


Figure 8:Tren Urbano organizational diagram

6.1.1 Information Structure

Designing an intuitive user interface was the most difficult part of the project. This decision was based on literature reviews, past experiences and examples from other similar projects. It is necessary to make the correct decision about layout, spatial organization, navigational systems, and information presentation in order to create a successful prototype that later can be expanded upon. The representational possibilities are endless, and depend purely on the availability of datasets. The question remained as to how to structure and link the different visual elements such as maps, text, videos, object-models, and images together in a logical manner. The challenges are to

create a realistic experience of the physical built environment of the Tren Urbano site for the students who have not experienced the actual place, and to create a framework in order to encourage students to participate and further develop and contribute to the site.

Carefully constructed visual elements provide the users with an understanding of the project site that otherwise could not be achieved. The ultimate goal of the information structure is to allow users to make sense of the physical characteristics, as well as other topics related to the Tren Urbano project.

6.1.2 Navigational Structure

A graphic designer has traditionally been able to control where the user can go and when, and what the user can and cannot do. On the Internet however, this has changed, and the user is the one who fundamentally controls the navigational steps. Therefore, the design needs to reflect this reality and support user-controlled navigation. Since the Internet is a navigational system, the most basic function therefore is the ability to click on links in order to navigate around a huge information base. It is necessary to provide the user with a navigational system that answers the following three questions:

Where am I? Where have I been? Where can I go?

Most importantly, users need to understand where they are so they can understand not only the site's structure but interpret the meaning of the link that was followed. The user's current location needs to be shown relative to the web as a whole and to the site's structure. It is helpful to have the same color scheme and layout for consistency and easy orientation. In the case of the Tren Urbano project, the user has the option at any point to go back to the homepage or to follow any of the non-spatial links such as to "student research," "map gallery," and "resources." In order to understand where they have been, users are provided with a "back" button on all pages to allow easy transfer from one information layer to the previous one. Knowing what links lead to previously visited pages is useful to learn the structure of the site, and to prevent wasting time going to the same page many times. To explore where the user can go, visible navigation options coupled with image maps are provided. Image maps include embedded links to indicate that there is more information available about the topic. To break up long pages and to avoid scrolling, structural links are presented that include an anchor to specify the exact location the given links follow. The following picture shows the introductory screen of the Tren Urbano system.

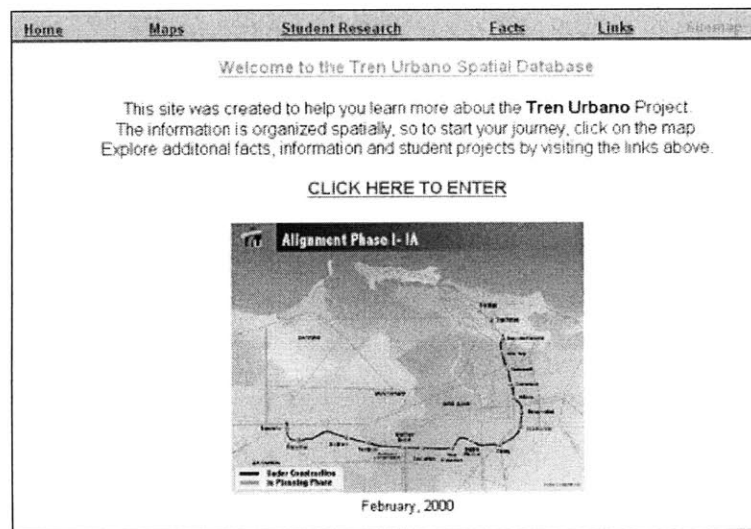


Figure 9: Tren Urbano homepage

6.1.3 Linking

Links are very important elements in this system because they connect pages and allow users to navigate among the web pages. A navigational link outlines the structure of the information space and allows the user to jump from one page to another. An example of this type of link would be a “home” button and links to a set of pages that are subordinate to the current page. An associative link is within the content of the given page. An example would be an underlined word, or image map, that points to more detailed information about the given topic. Given the heavy use of embedded frames, the creation of a free flowing system of links to all levels of information was technically and structurally very challenging. However, it is absolutely necessary to allow users to freely navigate among the data layers. The system is successful and fully functioning in this regard. The navigational system was constructed to always allow the user to jump to any other non-spatial sections of the system, or to go back to the homepage in one step. In addition, the user always has an option to go back and forth between information layers, however, he/she can step back and forth only one step.

6.1.4 Frames

Even though frames introduce a lot of constraints into the structure of the web-site, the author has decided to include them in order to allow the user a sense of consistency and a view of the given visual elements on the same page. As the figure below shows, the use of frames enables the viewing and comparing of two visual elements, in this case a site plan and additional imagery of the station to be examined at the same time. With frames, however, the user's view of information is determined by a series of navigational actions rather than one single action. The unit of navigation with a frame is different from the unit of a page. Another drawback of using frames is that the size of the page is reduced. Additional problems include the fact that many browsers cannot print framed pages appropriately and printing the full page is difficult with scrolling frames like the ones applied in the Tren Urbano project. Also, some browsers make it difficult to bookmark frames. In the Tren Urbano context accommodating free flow of navigation with three layers of embedded frames was very challenging from both a technical and

a design standpoint. The graphic below illustrates the most detailed level of information that was collected about the individual stations. Here, again, frames are used not only to create a consistent look, and to allow users to understand exactly where they are within the system, but also to allow simultaneous viewing of the proposed site plans and their corresponding current physical conditions.

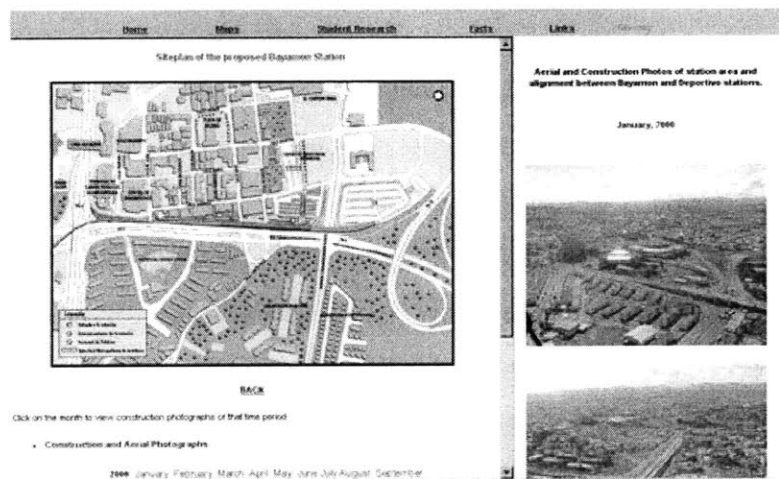


Figure 10: Uses of Frames in the Tren Urbano Prototype

6.1.5 Interactivity

Since users will want to visually explore the construction progress made at the Tren Urbano alignment, the author decided to represent the aerial video element in separate frames, forming different images for each time period. So far, there are two time periods available, but in the future this can be expanded to include a series of videos taken at different intervals. This way, the users can easily compare the construction progress that occurred between different time periods by simultaneously playing the videos. There are two categories that can be used to explore spatial-temporal patterns. The author has used the method of displaying spatially separated animation where two animated sequences are simultaneously displayed next to each other (see Figure 15). Another common method that could be incorporated into the system at a later date is transparently overlapping animation. For example, features of different maps showing construction progress over time can be placed on top of each other and animated in order to create the illusion of changing spatial-temporal patterns.

6.1.6 Multi-Platform Design Approach

Unlike with traditional GUI design (where the programmer can control every pixel), it is the user who fundamentally controls his/her navigation throughout the pages on the web. Therefore, designers need to accommodate and support this new approach. To make sure that the web site is viewable on most machines, the author designed all the pages for a small (800x600) monitor. It is best to design for a medium screen resolution capable of adapting to whatever screen size the user has. In order to achieve this, it is best to use percentages for tables, frames, and other elements instead of fixed elements. It is also important to make sure that the web pages work both in Netscape and Internet Explorer. Earlier versions of Netscape did not support frames and still have trouble with layers, which partly contributed to the decision of not using layers in this project.

6.2 Content Design

Content is the focus of the web user's attention. A quality content determines the site's usability. Multimedia has gained great popularity in recent years due to improvements in bandwidth and computer graphics quality. There are many technologies that support the use of animation, video, and audio to supplement textual information. The Tren Urbano project is currently distributed on a CD-ROM that addresses issues of slow downloading time that can severely impair the user's experience. The author has initially used the combination of cropping and scaling for all images in order to reduce downloading time in the future once the system is placed on-line.

6.2.1 Spatial Organization

The Tren Urbano system consists of three informational layers. On the homepage, the user is presented with a hyperlinked image map and textual navigational option. At this level,

he/she can link to more information about either the area between two stations or a particular station itself. Once the user clicks on the alignment section, he/she is presented with a large-scale aerial photograph depicting the area between the two station segments. From here, an interactive video is presented and an option of exploring further information about the two stations within the alignment. The station information layer contains a site plan as the reference point, while the right side of the page changes as the user clicks on different options to explore further information about the station itself. There is a horizontal cross-reference between the alignment page and the station page, allowing users to toggle back and forth, or return to the main menu to explore other options.

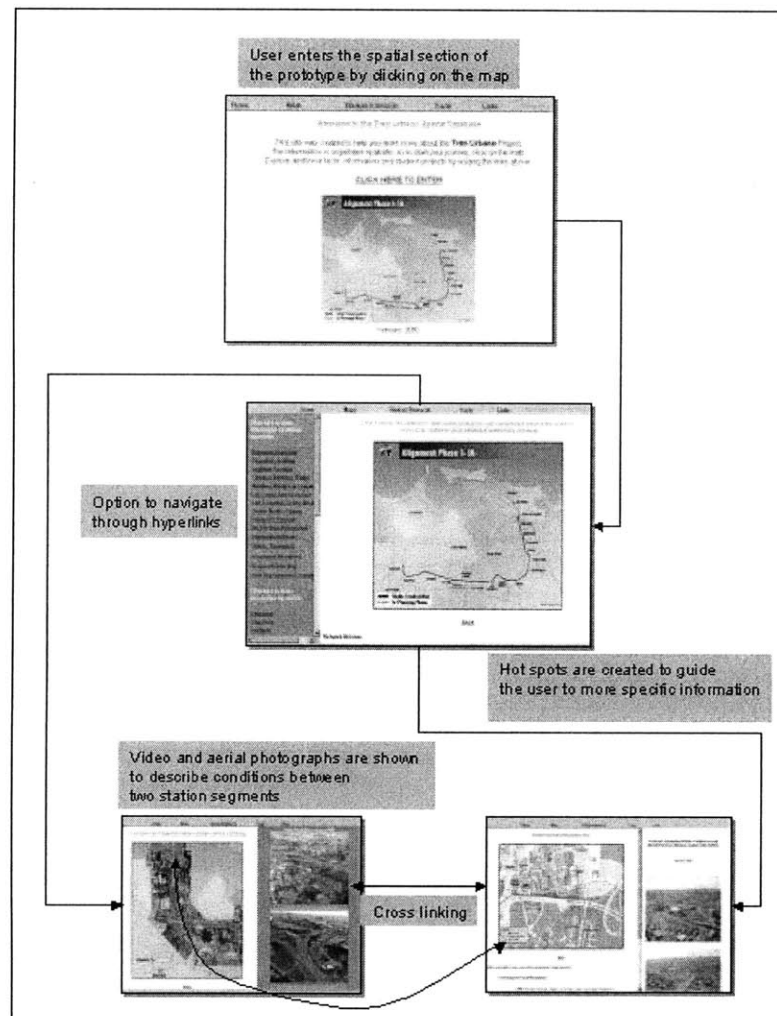


Figure 11: Spatial organization of the Tren Urbano prototype

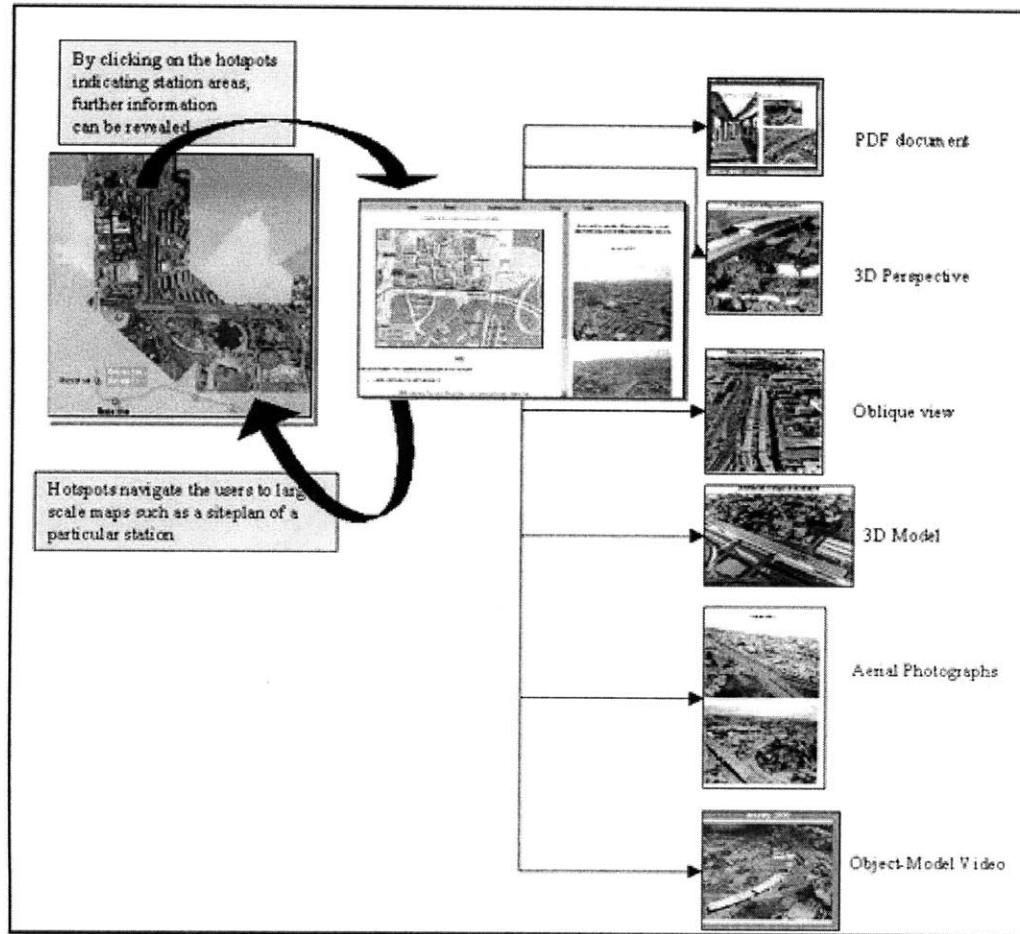


Figure 12: Multimedia elements and their organization for each station

6.2.2 Image Maps

The definition of an image map as related to this project is given by Raper (1997)

“When a hypermedia spatial database is integrated with coordinate-based spatial referencing such that each spatial ‘object’ has a stored location, the system can be defined as a hypermap.”

The idea of a hypermap actually dates back to the 1970’s when scientists at MIT developed an interactive application (Aspen project) whereby users could navigate around the streets, by clicking on the desired direction of travel. The user could also click on buildings and other items to learn more about them.

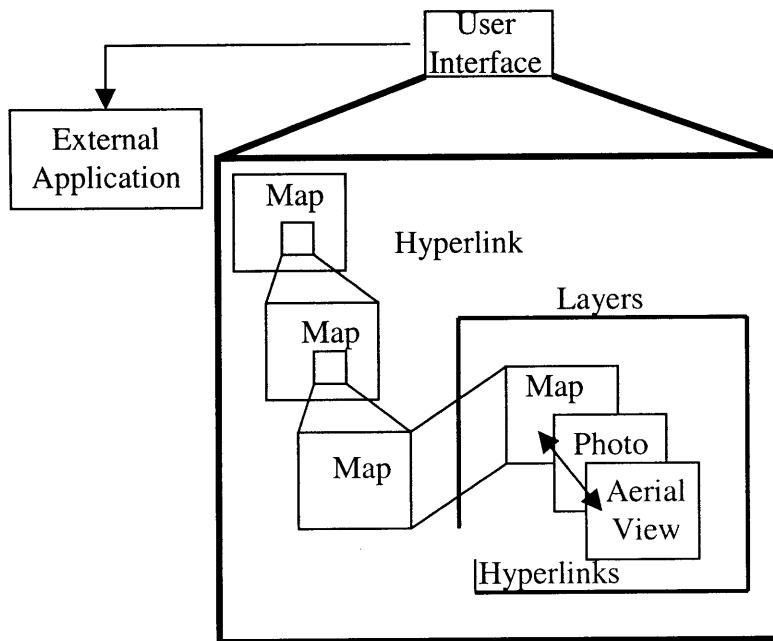


Figure 13: Imagemap

Image maps are “clickable” maps that allow users to access additional information about a particular topic or location of the map. Having access to a wealth of different information in a variety of formats, (such as photographs, animations, video, text, and audio) gives the user a rich representation. A hyperlinked image map is used on the main page of the Tren Urbano system because it is a very useful way of organizing spatially related data. All stations and station segments are hyperlinked to connect the user to additional information.

The image map in the Tren Urbano project is on the client side. It is useful to have an ALT tag for each of the link options, so users can understand immediately where the link is pointing before following it. The ALT tag is part of the HTML code that provides the user with information describing the link. The constraints image maps pose is that they are static and must be hard-coded. Perhaps, in the future, dynamic maps can replace the existing static image map. These could provide real time information to the users and allow them to dynamically update or change maps when new information (such as additional visual elements) are entered into the database.

6.2.3 Dynamic HTML

The author originally wanted to use a dynamic HTML method of Web authoring to allow more interactivity with users. For example, the user could pass the mouse over a specific location of a proposed site plan of a station and the corresponding photograph of that area could simultaneously appear. However, developing this feature proved to be unsuccessful for several reasons. First, there were too many existing photographs for each station to be identified and tagged individually. Moreover, creating dynamic HTML layers at such scale would make the system very susceptible to breaking and more difficult for users to contribute to the site successfully in the future. Also, frames and layers don't work together properly, so it was necessary to work with only one of these methods.

6.2.4 Navigable Videos

Animation (such as a navigable video) can greatly assist people with understanding complex information, in part because humans are good at understanding pictures. Videos are very useful when one needs to show underlying changes especially between two time periods as demonstrated in the prototype. Moving images have a powerful effect on users and serve several important functions such as showing continuity in transition, illustrating changes over time, enriching graphical representation, and visualizing 3D structures. Two-dimensional representations do not properly illustrate three-dimensional structures, so this method is an extremely good representational tool in the urban planning context, which involves building and natural three-dimensional structures.

Digital videos have recently gained popularity in the age of multimedia technologies and inexpensive computers. These new technologies allow for improved image digitizing and processing capabilities. Videography is the process of capturing, processing and understanding video images (Vlcek, 1988). Navigational videos are useful in representing space and time. To take advantage of these benefits, the author has used navigational video to assess the

development and progress of the construction of the train alignment. An additional benefit of this technology is the user's ability to control the speed and direction of the video. Thus, multiple videos can be played and be compared at the same time. The aerial fly-over videos were taped on the site in San Juan, then digitized, processed and cut into the appropriate sections to reflect the area between station segments.

For example, in the case of watching the progress of construction in the Tren Urbano context, changes between the stages are much easier for users to understand if these transitions are animated. Navigational videos can illustrate change over time, and this animation can be used to emphasize the three-dimensional nature of the area, making it easier for the users to experience the spatial characteristics of the environment.

There is, however, a great concern regarding the downloading time of the videos. In the Tren Urbano context, the CD-ROM delivery method compensated for this concern. When the system is placed on a network, it is highly recommended to indicate file size and approximate downloading time in parenthesis next to the files. It is a widely held belief that system response time must occur within about ten to fifteen seconds to keep users' attention.

On a positive note, research conducted by the Department of Computer Science at the University of Reading has shown (Ghinea, 1998) that the quality of video clips can be significantly reduced without the user noticing any significant loss of information. According to this study, beyond an existing threshold users cannot perceive an improvement in the quality of multimedia application. This is important to realize when developing an Internet based system because a user's understanding has serious implications for resource allocation and design issues. Also according to this study, there is no significant difference between the percentages of correct answers given by the users at different video frame rates. Findings indicate that frame dropping does not have a proportional impact on the user's capacity to understand video clip material. In order to reduce the size of the aerial flyover videos used in the project, severe frame dropping and maximum compression were used simultaneously to achieve the best result. Moreover, dropping frames might even be beneficial, as the user has more time in which to view each frame before it changes. According to this study, the conclusion was made that users have difficulty absorbing audio, visual and textual information at the same time. Instead, they tend to focus on one of these media at any one time, which implies that multimedia delivery should happen one medium at a time as applied in the Tren Urbano prototype.



Figure 14: Example of a navigational video

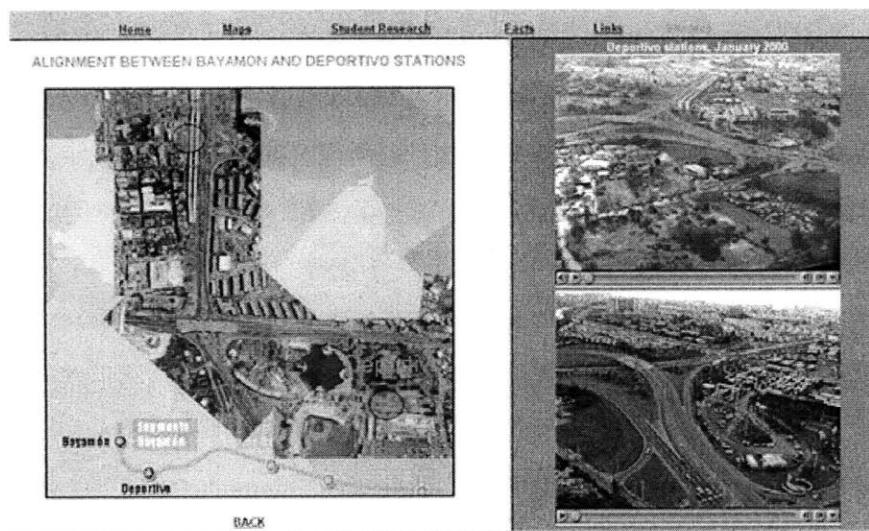


Figure 15: Comparing two videos at the same time from different time periods

6.2.5 Panoramic Videos

Panoramic object-model videos have the same benefits for user understanding as navigational videos, which is why they were used to illustrate the 360-degree dimensions of some of the stations in this project. Again, the aerial fly-over videos were taken at the site in San Juan and digitized, processed and converted into panoramic videos. The given stations are viewed from above allowing the user the option of panning around the station, or zooming in and out of it. The speed of the animation is fully controlled by the user who can spin the object 360 degrees and focus on the structure of the object. In the future, the site could include additional,

ground-level panoramic videos of all stations, which could be treated as videos and placed next to each other in chronological order for users to compare construction progress over time.

The ability to view objects dynamically will help urban planners to visualize planning proposals, so the integration of 3D with hypermedia is a natural evolution. Three-dimensional models can be anything from photo realistic panoramic videos (such as the ones used in the Tren Urbano context) or complex CAD drawings. According to Bodum, there are four different levels of abstraction which can be categorized as follows:

Near reality

Enhanced reality

Enhanced virtuality

Virtuality

Near reality includes panoramic videos that give only the illusion of 3D by stitching together many overlapping still images of an area such as a ground level panoramic video. *Enhanced reality* uses video or photographs as the background to the proposed objects that can be imposed upon the background. *Enhanced virtuality* is the opposite of enhanced reality, whereby a photograph or a texture map is overlayed on a CAD model to give a realistic image. *Virtuality* is a true virtual reality where the models are created as features in a CAD application. Some of the 3D models of stations resemble this technique. All these techniques can be used in the Tren Urbano context to eliminate misunderstanding and enhance the communication among the students, faculty and Tren Urbano professional, in addition to allowing the visualization of different alternatives of the proposed station plans.

6.2.6 Images and Photographs

Images and photographs are the main component in the Tren Urbano system used to describe the physical characteristics of the stations as well as their alignment. Images and photos of the alignment and station areas are correlated with map information in order to provide further visual information of the area. This helps users to understand the physical environment and

construction progress. The images and photographs were provided both by the Tren Urbano office and hand-collected during the January site visit. Photographs include images of the construction site taken every month in 1999 and in January of 2000. There are also oblique aerial photographs for each station area along with photographs of tunnels.

An additional advantage to using images is that they give the illusion of a three-dimensional space, unlike floor plans and maps. The following pictures show some of the images used in the project.

March, 1999



Figure 16: Construction photos of a station

Oblique View 2 of Bayamon Station



Figure 17: Oblique view of a station

3D Perspective of Bayamon Station

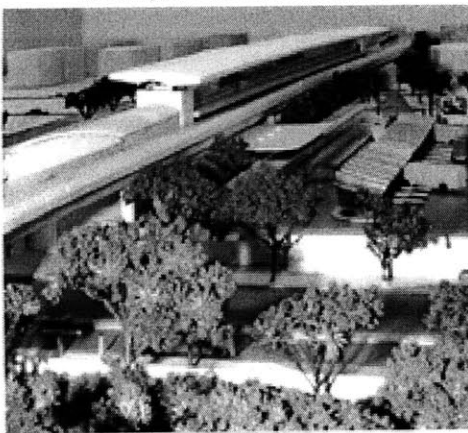


Figure 18: Perspective view of a station

3D Model of Bayamon Station

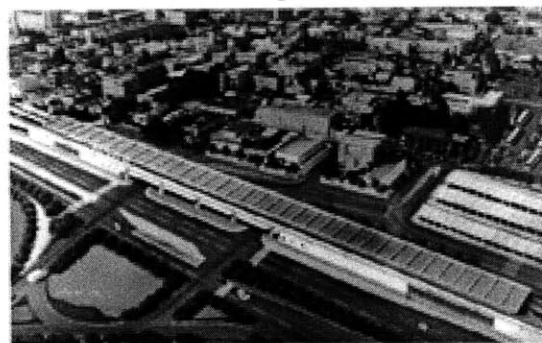


Figure 19: 3D model of a station

6.2.7 PDF Documents

Adobe Acrobat Reader software is an excellent plug-in application that can be easily embedded into any HTML document and automatically launched within the browser when the user calls the file. This software uses a PDF file format that has the unique advantage of being “read-only,” which gives a sense of security. For this reason, sensitive information on the Tren Urbano site such as student papers, research projects, or existing powerpoint presentations, were converted into PDF format and embedded into the HTML documents. The Adobe Acrobat Reader includes zooming and panning capabilities that are very useful in giving users a sense of interaction and control over the materials presented.

Originally, some of the maps within the project were to be embedded in a PDF file format, but unfortunately, as of yet, there is no way to connect frames and PDF files or dynamic HTML programming with each other. Because of this technical difficulty, the author decided to use frames instead in order to allow the simultaneous display of a reference point (such as a map) and a changing visual element such as 3D models, oblique views, videos and aerial imagery on the same page. An example of the embedded PDF document containing additional information is displayed below. This format allows users to view the file while also viewing additional visual elements displayed in the right frame of the page.



Figure 20: Embedded .pdf document providing information about a station

Student files were converted into a PDF format to provide both access and file security. In the future, the system could be expanded to allow students, faculty and Tren Urbano professionals to interactively add their own documents to this site, thus building an online, searchable library of resources. The diagram below illustrates the current structure of the

“student research” page where users have an option to search the database based on name, thesis title, department, or available online documents, and view the embedded PDF files within the page.

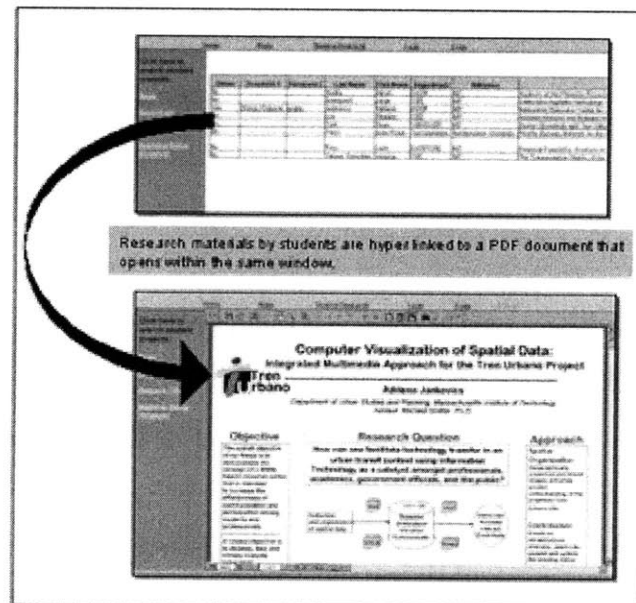


Figure 21: Embedded student documents in a PDF file format

CHAPTER 7

IMPLEMENTATION STRATEGY

7.1 Distribution Methods

Initially, the prototype was distributed on a CD-ROM that includes all necessary files, plug-ins, and a brief readme.txt file. It was expected that each of the research universities both in Boston and Puerto Rico would install the project on their local Intranet so students and faculty can view and evaluate the system. In the future, it is hoped that the project will be available online, so additional benefits of the Internet can be utilized (e.g. central distribution and interactivity with users). The decision by Tren Urbano officials to keep the site private at this time had major design and structural implications to the site. The current system offers several benefits to the Tren Urbano community. The project is available on a portable CD-ROM, which can be installed in any machine and used to aid presentations, discussions, or other meetings or environments where graphical representation of the Tren Urbano project are relevant. It is hoped that the prototype will actively be used not only by the students, but also Tren Urbano officials to help communicate the physical characteristics of the alignment.

7.2 Comparison of different delivery modes

Concurrent to the development of the Tren Urbano prototype, a powerpoint-based kiosk system was also designed and developed in order to compare the advantages and disadvantages of a stand-alone system versus web-based application. The goal of this project was to introduce the Tren Urbano project as a guided tour from student perspectives. The volunteers acted as tour guides, steering the viewers through the different subject areas they covered. This way the user could not only learn about the project, but also develop a personal contact with the participants. This stand-alone project has the advantage of being easily accessible, offer a great deal of reliability, and free from speed constraints. This is an important factor in a system like this that

relies heavily on large visual files and animations. Despite these benefits, a stand alone, closed system is not the most appropriate approach, for it can not be centrally updated, and can not contain interactive features (such as real time information and contribution that the Internet can provide). It is a closed system in which only one user can interact with the program at a time and user access can not be restricted through the program.

The current distribution method of a stand alone CD-ROM has the same advantages as the stand alone kiosk application, but the disadvantages are not that great. The transition from a CD based distribution to a Web based distribution can be relatively easy since the program's format is already in HTML format.

7.3 Benefits of web-based approach

A web-based system offers a high degree of flexibility whereby information can be easily updated, as well as offer interactivity to the user. Also, the Internet can be accessed regardless of the user's geographic location. This permits students in Puerto Rico and Cambridge to take full advantage of the system. The system also provides equal access to data and information to all its users. It has the capability to empower both students and professionals involved in the project by providing the necessary information and datasets that meet the needs of the users. It is also important to point out that using the Internet does not require high technical skills, so people who are less technologically savvy do not feel marginalized. Most people are familiar with the interface of the Web, so by providing the prototype in this format one can avoid learning new software or interfaces.

Internet-based applications have an ability to link text with video, audio, graphics, animations and other digital data to create multimedia presentations which in turn facilitate important cognitive processes and cooperative learning, reflection and problem solving. While student and professional involvement can be increased by an Internet-based approach, it cannot replace current practices of interpersonal interaction and communication.

The use of the Internet allows for the integration of a range of visual elements into one platform. This type of flexibility provided by hypertext and the Internet made a web based

approach the most beneficial. The Internet also provides an easy access to other online resources that enhance the experience of the user of the Tren Urbano project website.

In conclusion, the Internet is an excellent medium for the delivery of this type of project mostly because of the reach of a global audience and its scalability.

CHAPTER 8

EVALUATION OF DESIGN APPROACH

8.1 Evaluation Method

The evaluation of the Tren Urbano website included goal refinement, documentation in a form of a thesis, and evaluation based on questionnaires and interviews. While there are many evaluation methods (e.g. interviews, focus groups, observations and user counts), only questionnaires and interviews were used with selected students within the Tren Urbano community. In order to help the author assess the success of the prototype, some of Barndt's (1998) criteria were used.

What is the value of the results? Is the prototype appropriate and insightful?

Can the Tren Urbano community use this system to support decisions, and enhance communications among the users? To this date the author is unable to answer this question, but in time, as the system is used in the Tren Urbano office and in the other universities, one will be able to better address this issue. This system also takes advantage of the synergy that can result from integrated information sources. One of the objectives of this project was to address this question by bringing data together from a variety of sources. In the future, a fully developed resource center enabling multimedia linking can better explore relationships in data across various multimedia elements.

In the author's opinion, the greatest value of the prototype includes its efficient design approach that is scaleable enough for future expansion and easily maintained. Moreover, the site integrates various multimedia elements into one central depository that is organized by the geography of the Tren Urbano project and can easily be expanded as more data becomes available. The information is presented in an easily understandable format that can enhance the understanding of the project, especially for those users who are remotely located from the physical site.

Can the project be managed well?

Most importantly, is this prototype sustainable and scalable? Can the project be built upon? Does the foundation and current structure allow for enhancement, or would the project need to be rebuilt again? The author incorporated these questions into the design process and built a “skeleton” foundation that later on can be enhanced. Currently, the research project is a stand-alone application that is very easily managed and distributed. However, as the system goes on-line in the future, a dedicated server and a technical person will be needed to maintain and update the system as needed. This person could also develop additional interactivity capabilities (such as allowing users to upload images and other files to the appropriate place on the site), so eventually the system could sustain itself and be continuously built by the Tren Urbano community. Currently, maintenance and development of the site involves repetitive procedures—since the alignment consists of many stations that need to be updated separately. This calls for customized programming that could significantly reduce the time and complexity associated with common task procedures.

Finally, in order to ensure the success of this project one needs to increase the capacity of the Tren Urbano community to use the technology through technology transfer. This can be achieved by educating users about the purpose and usage of the system in order to empower them to better utilize this resource and encourage future participation.

What is the suitability of data sources such as animation and other visual aids to effectively communicate information about the given geographic location?

Available data is often limited, as in this context where data was difficult to acquire as well as incomplete in many respects. For example, GIS data was very limited, preventing the development of some useful thematic maps depicting socio-economic conditions around the San Juan metropolitan area. Maps and GIS data around station areas were also not available.

Data should be detailed enough to inform actions and should be scaled to the appropriate level in order to provide a focus. In this case, the most focused data sets included the visual representations of the prospective stations and surrounding areas such as the navigational and panoramic videos. Viewers of the system found the usage of animation a really effective learning tool to understand the changes of the construction progress.

How does one understand whether the multimedia tools the system provides are working? How does one know if users are benefiting from the application and gaining any new knowledge previously unavailable to them?

The issue of long-term evaluation is vital to find the answers to these questions. As the evaluation conducted during this research mainly involved less vigorous feedback evaluation from users, the author feels that more quantitative work needs to be done in this area once the site is in a networked environment. Not only usefulness of the information, but also quality of the current data and level of appropriateness needs to be evaluated.

8.2 Questionnaires

The ultimate goal of the prototype is to evaluate the relationship between visualization and increased collaboration, learning experience and communication among members of the Tren Urbano community. Because of time restrictions, however, this cannot yet be measured. The distribution method unfortunately does not allow for a quantitative way of measuring participation with counting hits for example or tracking the navigational path of the user. So, the only way to evaluate the usefulness and benefits of the project was through direct interviews and questionnaires. The following questions were distributed to some students of the project.

1. Did the information help you learn more about the Tren Urbano project?
2. What would you like to see that was not contained on the CD?
3. What information was most valuable?
4. What information was least valuable?
5. Was the structure easy to follow?
6. Was information easy to find and did it follow a logical sequence?

8.3 Feedback

While people liked the navigational structure and found the organization of information very logical and useful, they missed seeing more detailed information on the station level. For example, one student sought more in-depth information under the “additional information” link that launches an embedded PDF file. Unfortunately, there is no more detailed information

available at this time, but in the future additional pages can be added to the existing PDF files. All interviewed students expressed a desire to see a complete list of the posters and research summaries, or other documents on the site, and perhaps other executive summaries if available. One student also noted that more ground level photos of the station areas and alignment would be useful to better understand the context. Unfortunately, these can only be added if the students or staff of the Tren Urbano office provides us with additional ground level photos. These frequent requests for additional information demonstrate the success of the prototype, which served to arouse the interest and desire of the users to learn more about the project.

Another student wrote enthusiastically, “In completing a thesis on transit supportive housing development opportunities proximate to Tren Urbano stations, I kept abreast with the spatial orientation of station areas by periodically referring to the maps and images. This is a very valuable tool that should be placed on-line immediately.”

According to the students, some of the strongest features of the prototype include the combination of different media in presenting the details, which provides an opportunity to appreciate the most recent information. The flexibility of the web-based format means that it gives the designer an opportunity to enhance and update the information in near real time mode. Moreover, students were enthusiastic about the inclusion of current research by others, allowing them to monitor how graduate students’ research will impact the operations and decision making of the Tren Urbano in the years ahead. All respondents mentioned the ease of use that this web-based application offers, which allows users with varying levels of technological sophistication to easily navigate through the system.

Finally, the navigational videos were really a great addition to the learning process. As one respondent noted, “The inclusion of the digital video helped to put everything into perspective. This section of the website maintained my interest longer than most other features.”

8.4 Further Work and Implications for Tren Urbano Technology Transfer

A framework is needed to support the integration of multimedia and a spatial database that would integrate the different types of multimedia and allow the user not only to update and upload to the current database, but also to query and extract the necessary information.

Currently, there is no cross-link between video and text or video and other images. If there was a link between video frames and maps, users could search information based on particular frames in the video segments. For example, a user could click on a frame within a video segment of station A and B and immediately retrieve further information about that particular feature (street, building, highway, construction site, etc.). Users would have a way to contribute information to this central database by uploading files to the appropriate site.

A potentially great application in multimedia in urban environment, is to connect a video image to the exact location on the map. In the Tren Urbano context, this would have required very difficult programming techniques since an easy software application is not developed yet. First, each video frame would be linked to a GIS map and a database that would be searchable. Second, users could search for objects in the video and retrieve the appropriate information from the spatial database. Another possibility would be to allow users to stop at any frame of the video and see the corresponding physical location on the map. Currently Rostock University is conducting research in this subject area. (Bill et al. 1999)

Another possibility for further work is the integration of different types of multimedia, so changes in one type of medium would be reflected in the other. For example, students would automatically upload new images taken at the site of the Tren Urbano alignment and the changes would immediately be reflected on the image maps and the existing files. This would allow for added flexibility and greater integration that would aid in the creation of a spatial information clearinghouse. As Sventek (1987) describes, there are three logical levels of multimedia integration.

Physical level—the data from the separate media are multiplexed over a single physical connection. At this level, we have storage and distribution developments such as CDs, compression standards for images and videos. In the Tren Urbano context, digital data were standardized and converted into common file formats for easy maintenance and updating.

Service level—the interaction between an element of a multimedia application and its media are achieved through a common, service interface. At this level the developments include enhanced architecture, multimedia workstations and toolkits to enable dynamic images to be displayed in various applications. In the Tren Urbano system, plug-ins such as QuickTime movie player and Adobe Acrobat Reader were integrated into the HTML files, so users could automatically call these applications from within the project.

Human-interface level—describes the presentation of the different media to the user. Here, one can have cross-media links, dynamic presentations and hypermedia. These features are all incorporated into the system to enhance user experience.

8.5 Conclusion

There were several important lessons learned during the course of this research project. Most importantly the author found that in order to ensure the success of a project of such scale, it is necessary to address and understand the institutional concerns regarding implementation strategy and information access as early as possible. In this research project, the institutional decision of keeping the project off-line clearly had a major impact on some of the design and technical issues in addition to significantly altering the original implementation strategy.

It is also important to focus on the core audience (in this case the students of the Tren Urbano research group), in order to facilitate the development of a system that addresses their needs.

The author also recommends developing a working prototype early on in the development phase to gain momentum and use it as a starting point for additional discussion with users. Data collection and technical issues always take more time than initially estimated, so it is very important to consider this factor when planning a project such as this one.

This prototype gives students, faculty, and the Tren Urbano staff the opportunity to view information from different perspectives in a single application by linking text, graphics, pictures, videos, and presentations without the constraints of linear progression of the material. It is hoped that the project will be built upon and expanded to include additional real time information capabilities, such as annotation and real time user contribution to the site. However, it must be noted that while a web based approach can link users through a network, it requires careful management and vigorous maintenance.

This thesis described the technical issues and design strategies in developing an online collaborative system for the Tren Urbano community. It can be concluded that the existing system can provide valuable, previously inaccessible information about the context and physical characteristics of the Tren Urbano site while freeing users from locational and time constraints.

The system offers an easy access to relevant, up-to-date digital information that can significantly reduce the effort associated with manually capturing and retrieving data. This also reduces the risk of data duplication and inconsistencies. Moreover, it is hoped that by having this project available to the members of the Tren Urbano community, it will encourage information sharing, among the students who can benefit from having access and knowledge of the various research projects currently undertaken by their peers. By providing this new channel of communication, it is hoped that there will be increased communication and new collaborative contacts formed among the different members. When working together and establishing connections, relationships and other benefits may evolve that will serve as a stronger bond among students from various institutions and geographic locations.

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